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ACCURACY OF POLYETHER VS PLASTER IMPRESSIONS FOR LONG-SPAN
IMPLANT SUPPORTED PROSTHESES

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ACCURACY OF POLYETHER VS PLASTER IMPRESSIONS FOR LONG-SPAN IMPLANT SUPPORTED PROSTHESES

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A research report submitted to the Faculty of Health Sciences, University
of the Witwatersrand, Johannesburg, in partial fulfilment of the
requirements for the degree of MSc (Dent)

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DECLARATION

I, George Botha von Berg, hereby declare that this dissertation is my own work. It is being submitted for the degree of MSc (Dent) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Signed by:

.....

George Botha von Berg

On this..... day of..... 2007

To my father, Dudley Albert von Berg, who completed his BSc at the University of the Witwatersrand during the difficult post-war years, and an MSc at the same institution during the 1960s.

ABSTRACT

Two different implant impression materials viz. a polyether (Impregum ®) and a plaster (Plastogum ®) impression material were used and compared with respect to the accuracy with which abutment positions were reproduced from a stainless steel master model containing five implant analogues. Ten polyether impressions and ten plaster impressions were taken and cast in stone. The positions of the precision impression copings on the twenty impressions were measured using a Reflex Microscope. The positions of the implant analogues on the twenty casts were also measured and compared to the positions on the stainless steel master model. Statistical analysis indicated significant differences between the polyether impression and the plaster impression for full arch implant supported prostheses. The use of plaster resulted in smaller interabutment error but with less predictable variance in dimensions.

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1. INTRODUCTION

Osseointegrated implants are a successful way of replacing missing teeth with long-term reliable restorations, whether for single teeth, partial or full arch prostheses. During the trial fitting of a long span prosthesis, the framework often does not fit passively. This may transfer detrimental or even harmful forces onto the implant-bone interface, resulting in complications, including loss of marginal bone and integration, framework fracture and gold screw loosening. It is thus imperative to find the most accurate way of transferring the information from a patient's mouth to a master model on which the prosthesis will be manufactured. Techniques for perfecting the precision of fit of the prosthesis have not been fully mastered in dentistry and therefore various impression and manufacturing techniques have been employed by various authors. The passive fit of the implant-borne metal framework is a prerequisite to minimise the above-mentioned complications.

Authors have made use of various impression techniques to accomplish a passive-fit.²⁰⁻²² Some studies find no difference between various impression techniques while other studies indicate a significant difference.^{21-28, 30, 31} The use of plaster as an impression material has been recommended in some studies in order to eliminate the potential for error in contrast to using elastomeric impression materials.

2. LITERATURE REVIEW

It has been shown that dental implants have a very good prognosis over a long period of time, with predictable results especially for full arch prostheses in edentulous jaws.¹⁻¹⁴ The first edentulous patients were treated in 1965.¹ Since then, a number of clinical complications have been described.² Gold screw fracturing and screw loosening were more frequent in prostheses which were supported by only two implants in partially edentulous restored cases. Even though implants can be used in short-span bridges,³ fewer complications occurred with the use of more implants supporting a prosthesis.⁴

Iglesia and Moreno¹⁵ describe passive fit as the “circumferential and simultaneous contact of all the abutments on their respective implants, and of all the gold cylinders of the prosthesis on their respective abutments. “ The authors made a plaster key that splinted the abutments, and when tightened in the absence of passive fit, the plaster fractured. Factors affecting the accuracy of fit begin with the impression techniques and materials. Comparing the accuracy of polyether impression material with plaster for long span implant supported prostheses is one of many factors that have been considered to make the metal framework of such prostheses more passive fitting in order to eliminate stress on the components.^{28, 38} Elastomeric materials have been used traditionally, while plaster is a stable and accurate material, and therefore a possible choice for accurate reproduction of implant position.

1. Importance of a passive fit:

i) Mechanical response

It is important to achieve a passive fit between components in order to eliminate mechanical failures which may include screw and abutment loosening or fracture, or fracturing of either the prosthesis or implants.^{12, 16} There may be reasons for failure other than the non-passive fit of components. Lekholm et al.⁹ found that most failing implants were related to implant length and poor maxillary bone quality. Zarb and Schmitt¹⁰ suggest that clinical stress loading, for example parafunction, may lead to loosening or fracturing of screws. Screw fracture normally follows screw loosening, the cause of which was difficult to establish.¹³

During the try-in stage of the metal framework it was found that the level of static stresses caused by fit discrepancies is dependent on the shape and location of the gap(s), interabutment distance, and the shape, dimensions, and the rigidity of the metal of the superstructure.¹⁷ There is a positive relationship between the size of the fit discrepancy and the magnitude of stress on the superstructure. The preload (tension due to tightening) in the gold screw is used to bring the mating surfaces closer together, which makes the screw vulnerable to fatigue fractures and loosening. Kan et al.¹⁸ described various clinical methods to evaluate implant framework fit.

ii) Biological response

Bone response may lead to non-integration or crestal bone loss around the implant.

A study by Jemt and Book ⁵ shows that none of the prostheses presented had a completely passive fit to the implant, with a maximum three-dimensional distortion of 275 μm , and a mean marginal bone loss of 0.5 and 0.2 mm for the 1-year and 5-year groups respectively. They concluded that there had to be a certain biological tolerance for misfit. Another finding was that no orthodontic bone remodelling took place around the implants due to these forces induced by the misfit, although Jemt and Lekholm ⁸ found bone deformation resulted between implants that were subjected to an ill-fitting framework. Therefore stress introduced into the implant system may still be present years after prosthesis placement. Strain gauges attached to an abutment indicated that a significant force was introduced on the implant when a fixed prosthesis was connected.⁶ The authors found that a greater tension/compression load on the implant was introduced by a fixed prosthesis compared to that of an overdenture. A poor fit could hence introduce tremendous stresses in the system which may lead to implant failure or metal fatigue fractures. Generally, more problems were found in maxillae compared to mandibles.⁷

Jemt and Lekholm ⁸ refer to dynamic and static loading: dynamic forces arise due to chewing, and static loading is the result of tension in the tightened gold screws of an ill-fitting framework.

2. Factors influencing passive fit:

a). General

Regardless of some problems like improper implant placement¹¹ and bending overload,¹² the predictability of Brånemark implants has been confirmed.¹³ Jemt and Lie¹⁹ suggest that distortion is significantly higher in the maxillary arches due to the curvature of the implant arch and larger number of implants usually placed in the maxilla. It may also be related to increased alloy content in the castings and poor alignment of implants.

b). Impressions

i) Impression technique

The next factor that contributes towards the precision of the prosthesis is the impression procedure. The procedure may be affected by the technique (open tray or closed tray) to be used. The impression technique comprises using square direct or tapered indirect transfer copings.²⁰ Numerous studies were done where the square impression copings were either splinted or left unsplinted.²⁰⁻³¹ Some square transfer copings were splinted with Duralay or another acrylic resin, with²¹ or without reinforcement with dental floss, or reinforced with carbon steel pins,²² steel burs²³ or orthodontic wire.²⁴ Vigolo et al.^{25,26} used square impression copings sandblasted and coated with the adhesive recommended by the manufacturer of the impression material. They found this technique highly successful, providing greater accuracy. Goll²³ used gold cylinders as transfer copings, splinted with Duralay, reinforced with steel burs and covered with impression plaster. He recommends machined componentry because they are more accurately manufactured. Assif, Marshak and Schmidt²⁷ splinted the transfer

copings directly to an acrylic resin custom tray. Copings splinted to each other with resin proved to be more accurate than the custom tray method. Assif et al.²⁸ also found that using autopolymerizing acrylic resin proved to be significantly more accurate than dual-cure acrylic resin as a splinting material. It was found by Philips et al.²⁹ that tapered copings may distort the impression material upon removal. Carr²⁰ also found the direct transfer method to be the most accurate due to the deformation of impression material with the indirect method. The results of the above-mentioned studies were not conclusive on whether the impression copings should be splinted^{22, 23, 25 - 28} or not^{21, 24, 30, 31}.

ii) Impression materials.

The selection of the most accurate impression material is the objective of this study. Traditionally there are six different types of impression materials in dentistry: agar hydrocolloid (reversible), alginate hydrocolloid (irreversible), polysulphide rubber, condensation-cured silicone rubber, addition-cured silicone rubber, and polyether rubber.³² This study, will however, concentrate on a seventh material, i.e. impression plaster. A study done by Linke, Nicholls and Faucher³² shows that all materials tested produced casts with an arch perimeter larger than the standard reference model. The reversible hydrocolloid showed the least interabutment distortion and the irreversible hydrocolloid the most distortion. It appears logical that reversible hydrocolloids should be used, but they are seldom used today due to the technique's sensitivity and equipment requirements.

It has been proved by Finger and Ohsawa³³ that different impression materials have different setting contraction values. A study was done by Wee³⁴ to determine the amount of torque required to rotate a square impression coping in an impression. He also compared dimensional accuracy among various groups of impression materials with a travelling microscope. Polyether was found to produce the highest overall torque values and was significantly more accurate. This was followed by addition cured silicone and polysulphide materials. The casts made from polyethers and addition cured silicones were significantly more accurate than casts made from polysulphide impression material. The use of either polyether or addition cured silicone impression material is therefore recommended for direct implant impressions. The high dimensional stability and coping torque of polyether has made it the impression material of choice for taking impressions for full arch implant supported prostheses.³⁴

Comparing addition cured silicone (AS), condensation cured silicone (CS), polysulphide (PS), and polyether (PE), Johnson and Craig³⁵ found that AS showed the smallest change in vertical dimension, AS and CS had the best recovery from undercuts, and AS and PE were the least affected by delays in pouring time. Akça and Çehreli³⁶ found no difference between the results of Impregum, (a polyether), and Panasil, (a polyvinylsiloxane). A combination of silicone impression material and impression plaster was described by Eid³⁷, and a combination of polyether and plaster was described by Inturregui et al.³⁸, where the polyether alone resulted in the closest duplication of the master cast. Impression plaster and irreversible hydrocolloid were

also combined by Nissen et al.³⁹ in partially edentulous patients. Plaster was used to splint the transfer copings. Assif et al.²⁸ also found plaster to be the impression material of choice in completely edentulous patients, since, in their opinion, it is less time-consuming and cheaper.

iii) Impression Trays

Tautin⁴⁰ used a rigid thermoplastic impression tray which was manufactured in the patient's mouth from softened modelling compound. According to Johnson and Craig⁴¹ a custom tray is the impression tray of choice. Moseley and co-workers⁴² predicted the maximum stress that the impression tray encountered during removal of a complete impression from the oral cavity. For autopolymerizing polymethyl methacrylate resin trays the yield strength is sufficiently high to safely assume that the tray will not distort under removal forces. In their study, Eames and co-workers⁴³ constructed trays with 2, 4, and 6 mm space for impression material and found that the 2 mm spacing provided greater overall accuracy for polyether.

iv) Casting of impressions.

Casting of the impressions may be influenced by humidity and temperature, water/powder ratio, amount of vibration and spatulation used.⁴⁴

v) Component tolerances.

Machining tolerances between implant components should also be considered. Ma et al.⁴⁵ conclude that machining tolerance determines the degree of movement that is

possible between paired components. Tolerances exist between abutment, impression coping, stainless steel abutment replicas, and gold cylinder. To ensure an intimate fit, there is always an inherent machining tolerance between the connecting surfaces. The two factors that contribute to machining tolerances are dimensional variation and surface roughness. The tolerances measured between the abutment and gold cylinder were 23.1 μm , and those between the stainless steel abutment replica and gold cylinder were 37.1 μm . These values were found to be significantly different ($P < 0.05$) which indicates that a passive fit obtained in the laboratory may not guarantee a passive fit in-vivo, as the passive fit in the laboratory may be outside the tolerance range of the in-vivo components. Hecker and Eckert⁴⁶ found that the machining tolerance of the stainless steel analogue and gold cylinder was significantly larger compared with that of the abutment and gold cylinder. This may cause a prosthesis that appears to fit in the laboratory to have a misfit of greater proportion in the clinical setting.

Southern Implants, which were used in this study, have a component tolerance of 0.01 mm for critical implant components like the hex of an implant. The 2.7 mm wide hex could be 2.69 to 2.71 mm. It has a tolerance of 0.05 for non critical components like the length of an impression coping for instance.

c). Framework manufacturing

As far as manufacturing of the metal framework is concerned, the computer assisted design/computer assisted manufacturing (CAD/CAM) procedure uses machined and laser-welded titanium frameworks which are manufactured by copy milling sections of an acrylic resin framework pattern in grade 2 titanium and then laser welding the

sections together.⁴⁷ Jemt et al.^{48, 49} found that the welded titanium frameworks are as accurate as gold alloy castings in a fixed prosthesis. Takahashi and Gunne⁵⁰ found the fit of the Procera system, produced by the CAD/ CAM technique, to be significantly better than that of frameworks made with a cast gold alloy. After studying six implant systems, Lang and co-workers⁵¹ found that the CAD/CAM produced Procera abutment should be considered for universal application.

When frameworks don't fit passively they need to be sectioned and indexed with self-curing acrylic. Of the index materials available, Cho and Chee⁵³ found that G.C. Pattern resin has a comparable accuracy to Duralay acrylic resin, but has a setting time of only three minutes compared to Duralay's seven minutes, which saves operating time. Mojon et al.⁵⁴ also compared two index materials: Duralay resin had a volumetric shrinkage of 7.9% and Palavit G. resin 6.5%, compared to the 21 % shrinkage of pure methylmethacrylate. The authors also analyzed the influence of powder-to-liquid ratio on dimensional change of the index material and found that adding more liquid to the mix increased shrinkage.

d). Mandibular flexure

Hobkirk and Schwab⁵² found that mandibular deformation of up to 420 µm can be encountered upon jaw opening, which should be considered both when taking an impression and during placement of a mandibular fixed prosthesis.

3. PURPOSE OF THE STUDY

The purpose of this study was to compare the dimensional accuracy of polyether and plaster impressions, and their resultant casts when compared to a stainless steel master model. The null hypothesis is that there is no difference between polyether and plaster impression materials relative to the master model.

4. MATERIALS AND METHODS

Testing Device

A stainless steel plate containing 5 stainless steel implant analogues (LS12, 3.75 mm, Southern Implants, Irene, South Africa) was used as a master model for impression taking (Fig. 4.2). The model represented an occlusal arch with five implants for a full arch implant supported prosthesis. The analogues were fixed by machine pressing into the baseplate and retained in the model by small locknuts preventing any rotation.

The analogues were numbered 1 through 5 from left to right (Fig. 4.3). Implant analogues numbers 2 and 4 were placed at an 8° lingual inclination to represent the clinical situation. Precision impression copings (CB12P, Southern Implants) were used which were torqued down onto the model to 10 Ncm (Fig. 4.4) before impression taking.

Impression taking

Standard acrylic impression trays (Fig. 4.5, 4.6) were manufactured (Excel Special Tray Material, Wright Health Group Ltd) on a template over the baseplate to ensure standardization of size and shape and a 2 mm spacing under the trays.⁴⁰⁻⁴³ Windows were cut into each tray to expose the transfer copings and guide pins. The windows were covered by a single layer of pink baseplate wax. (Kemdent no 4, Associated Dental Products, Swindon, UK)

The trays were left to cure for 24 hours before impression taking. Ten polyether impressions (Impregum ®, Pentamix Lot 202589, exp 2007-03, 3M ESPE, AG Seefeld, Germany) and ten plaster impressions (Plastogum ®, Harry J. Bosworth, Lot 0309-492, exp 2006-09, Skokie, Illinois) were taken of the master model complying with the manufacturers' instructions for use. ESPE polyether adhesive (Lot 126976, exp2005-02) was used for the Impregum impressions. Two coats were put on the trays, separated by 15 minute's drying time.

The ten polyether impressions were first taken with the 50 available precision impression copings (Fig. 4.7). Measurements of the polyether impressions (Fig. 4.14) were done on the Reflex Microscope before their stone casts were poured and measured. Once the casts had been made, the same 50 impression copings were used to take the ten plaster impressions (Fig. 4.16). First the plaster impressions were measured under the Reflex Microscope, and then their respective stone casts were poured and measured.

Impressions were taken in a controlled environment with temperature ranging from 19.5 °C to 20.3 °C for the polyether impressions, measured with a Supco THC 200 hygrometer. The values during plaster impression taking were 20.5°C to 22.2°C. The temperature ranges differed between the two impression materials as polyether and plaster impressions were taken on different dates. The reason for this was that the stone casts of the polyether impressions had to be made first. Only then could the same 50 impression copings be used for the plaster impressions. It is unknown to what degree the measurements were affected by this small difference in temperature.

The impression materials were mixed according to the manufacturers' recommendations and left for at least 15 minutes before removal from the master model. After removal of the impressions, stainless steel implant analogues (LS12, Southern Implants) were attached to the precision impression copings. This was done without disturbing the impression copings in the impression by holding the analogue in a clamping device (Fig. 4.8), and torquing the two components to 10 Ncm with a Southern Implant torque wrench (Figs. 4.9, 4.10 and 4.11). Casts were poured in stone, namely Pemaco-CD Peach (Pemaco Incorporated, St Louis, MO, USA) according to manufacturer specifications under normal laboratory conditions (Figs. 4.15 and 4.17).

Measurements

Measurements of the polyether and plaster impressions, and the respective casts were taken on the Reflex Microscope (Reflex Measurement Ltd., Greenways, Ditchat, Somerset, UK) (Fig. 4.12). The Reflex Microscope is an optical plotter which measures to an accuracy of 1 μm . It is linked directly to a microcomputer and allows direct three-dimensional measurement (x, y, and z-plane) of irregularly shaped objects up to 100 mm maximum dimensions. A small diameter light spot which can be set at 20 μm , 10 μm or 5 μm size appears in the field of view (Fig. 4.13). It is mainly used to calculate linear dimensions between two points. It gives an operator measurement error of less than 0.2 mm for linear distances, and a mean undermeasurement of 0.28%, which compares favourably with other measuring devices (Speculand, Butcher, Stephens⁵⁵).

The x and y planes are determined by moving the object table to the left and right, or forwards and backwards. The z-plane is determined by moving the ocular piece up or down, which brings the object into focus in the same plane as the light spot. During measurement temperature ranged from 21.8 °C to 26.2°C. The temperature range has no significant effect on the master model as the thermal expansion coefficient of stainless steel is equal to $10^{-5}/^{\circ}\text{C}$.

Measurements of the master and stone models were made on the top corners of the hex of the analogues. The 10 μm light spot was placed at a tangent to the outermost edge. (See Fig. 4.19). Similarly, when measuring the impressions, the light spot was placed

at a tangent to the innermost corner of the precision impression coping which coincides with the position of the analogue's outermost corner (Fig. 4.18). Each impression and each cast was measured three times, from which a mean value was calculated. The stainless-steel master model was measured 30 times to ensure consistency during the experiment. Distances were compared between the polyether impression, plaster impression and the master model for specific positions, and also between the different casts and the master model.

These are the 10 measurements of the inter-implant distances (taken 3 times each) that have been taken for polyether and plaster for both impressions and casts:

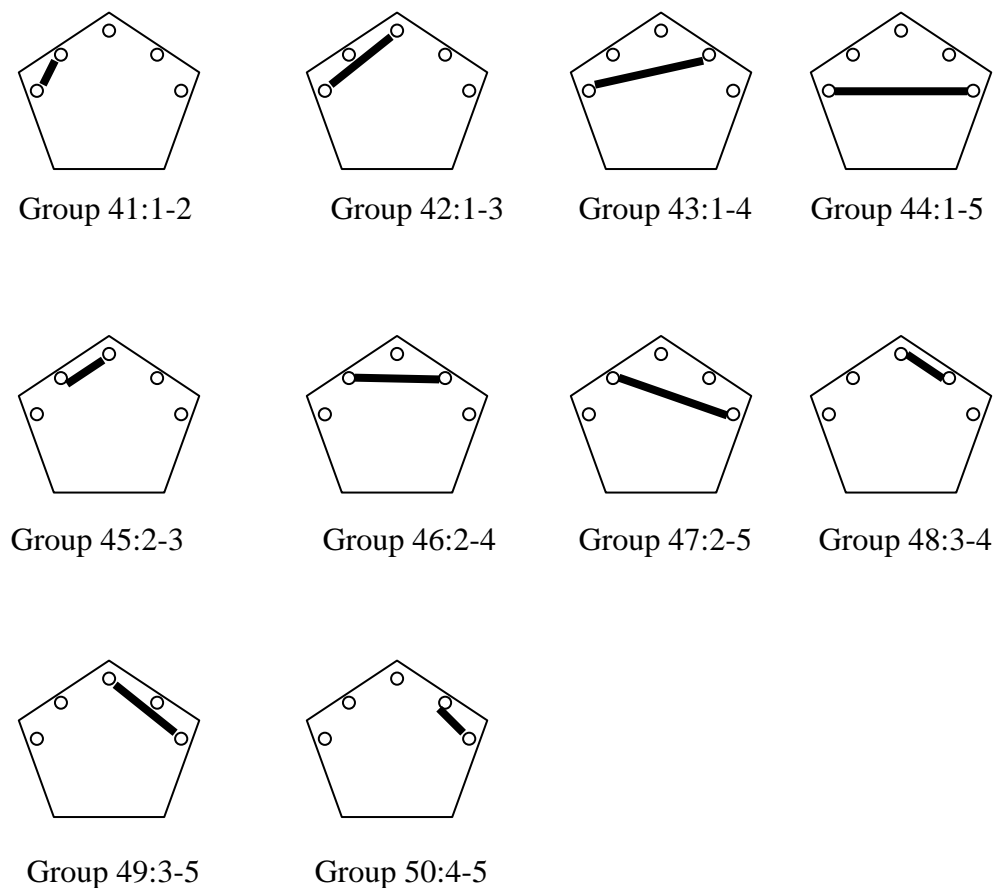


Fig. 4.1 Ten Measuring Positions

PHOTOGRAPHS



Figure 4.2 Stainless Steel Master Model

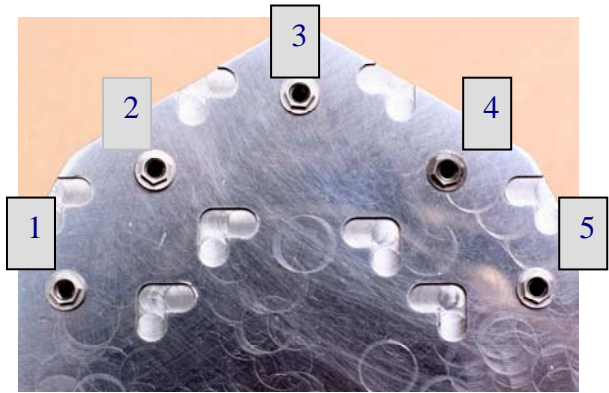


Figure 4.3 View of Stainless Steel Model with Implant Analogues Numbered



Figure 4.4 Stainless Steel Model with Precision Impression Copings in Place



Figure 4.5 Acrylic Impression Tray

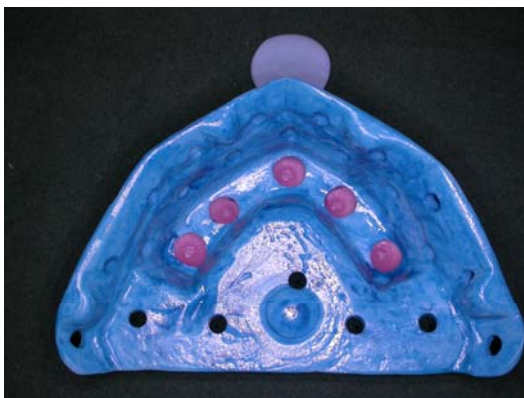


Figure 4.6 Inside of Impression Tray



Figure 4.7 Polyether Impression



Figure 4.8 Analogue Clamping Device



Figure 4.9 Southern Torque Wrench



Figure 4.10 Torquing Impression Coping onto Implant Analogue



Figure 4.11 Polyether Impression with Implant analogue in Place

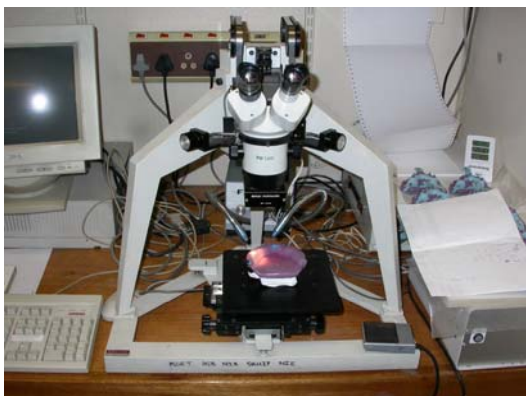


Figure 4.12 The Reflex Microscope

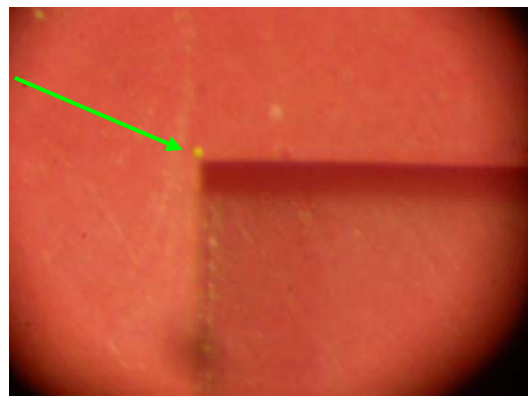


Figure 4.13 The Floating 10 µm Light Spot



Figure 4.14 Numbering of Copings on Impression

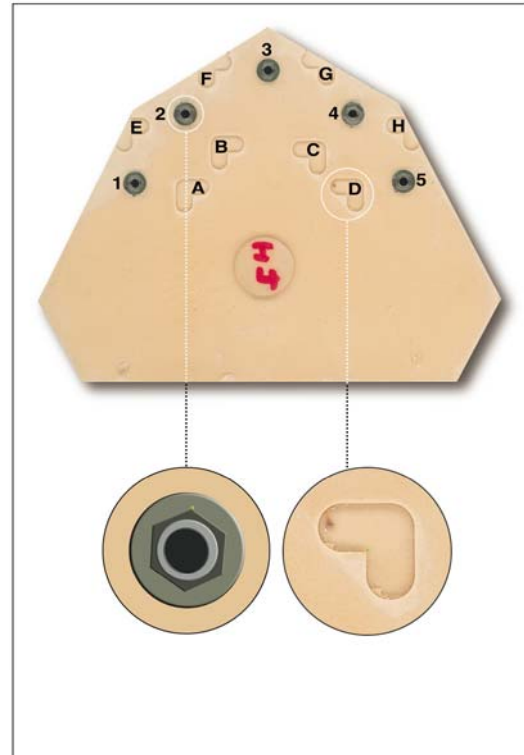


Figure 4.15 Numbering of Analogues on Cast from Polyether

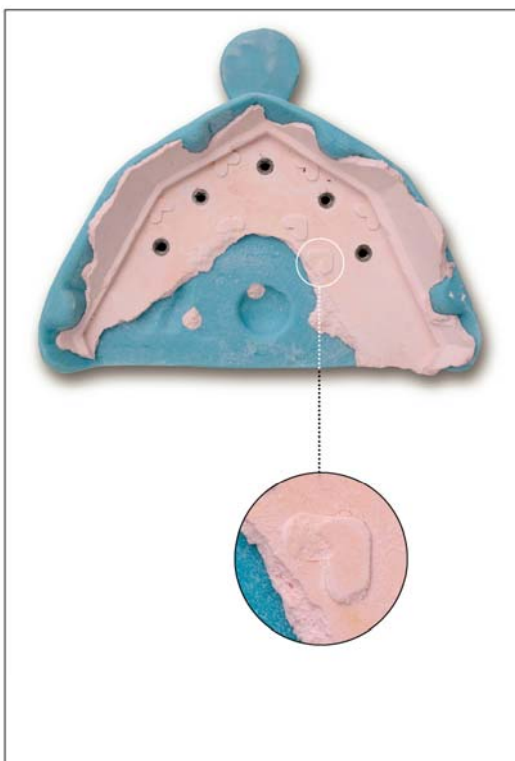


Figure 4.16 Detail of Plaster Impression

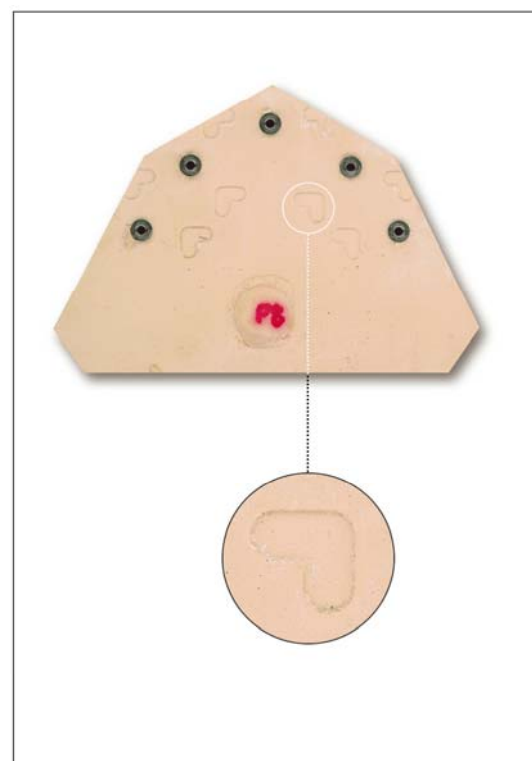


Figure 4.17 Detail of Cast from Plaster

Measuring Positions:

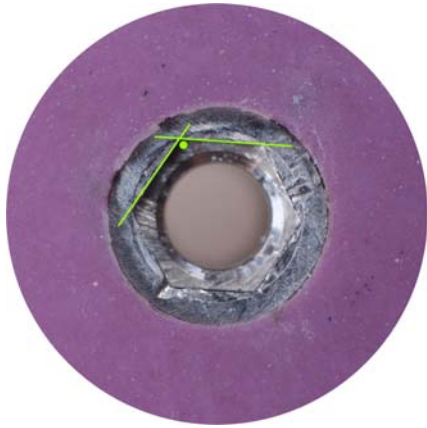


Figure 4.18 Position of Light Spot at Tangent to Inner Sides of Coping in Impression

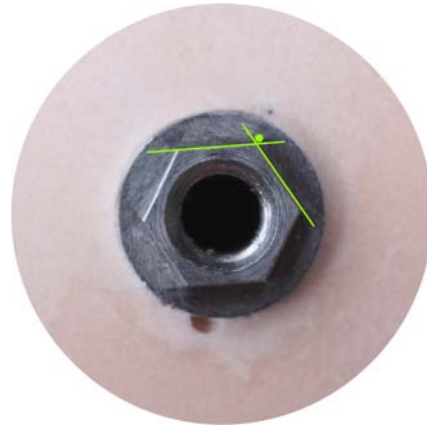


Figure 4.19 Light Spot at Tangent to Outside of Analogue in Cast

5. RESULTS

Methodology

The data was analyzed using descriptive statistics and the use of ANOVA (Analysis of Variance) to compare polyether, plaster and the stainless steel (SS) model, for both the impressions and their resultant casts.

Results

General

A two-way ANOVA was used to compare the casts from polyether impression material and the casts from plaster impression material with respect to the distances between the five implant analogues. The results indicate that there is a significant difference among the two impression materials and the SS model. Significant differences also exist among their resultant casts and the SS model for all but one of the interimplant distances. The only exception is the result for the casts of group 46 which relates to the distance between implants 2-4 ($p = 0.4836$) (Fig. 5.1). This is the only group where there is no significant difference among all three measured models, i.e. the two different casts and the stainless steel master. This group do, however, show a significant difference.

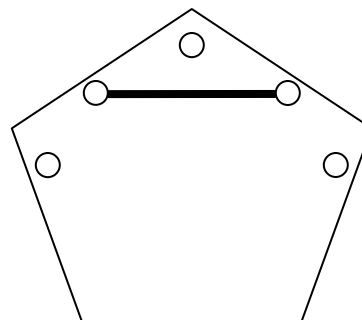


Fig 5.1 No significant difference for casts and SS
master model

Variability

The results show considerable variability within and between the samples. The polyether impressions and casts show a greater consistency than the plaster impressions and casts, although significantly different from the stainless steel model.

Even though the measurements for plaster are more inconsistent than for polyether, generally the mean plaster values approximate the stainless steel values more closely than the polyether values do.

A. Impressions:

a) No significant difference ($p > 0.05$) between:

Plaster/SS



Polyether/SS



Plaster/Polyether

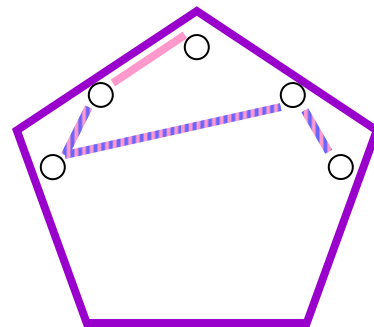


Fig. 5.2 No Significant diff: Impressions

b) Significant difference ($p < 0.05$)

Significant differences were found in the following areas:

Plaster/SS

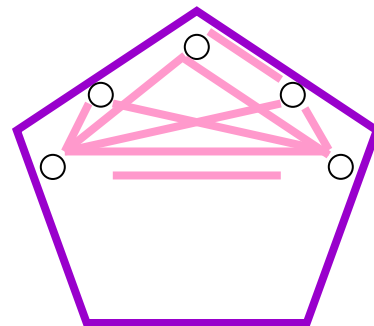


Fig. 5.3 Significant diff. Pl/SS

Polyether/SS

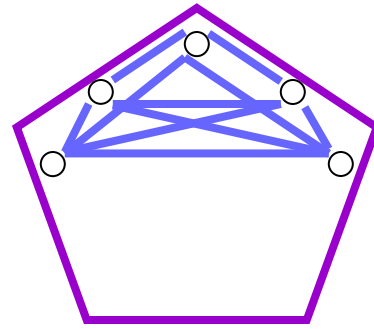


Fig. 5.4 Significant diff. Imp/SS

Plaster/Polyether

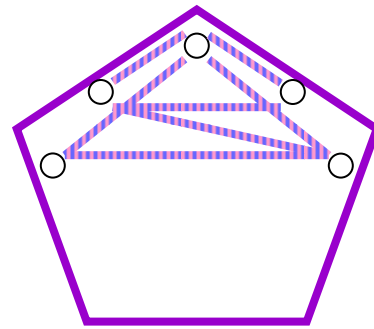


Fig. 5.5 Significant diff. Pl/Imp

i) Plaster/SS

Plaster and stainless steel differ significantly ($p < 0.05$) in all but one area: i.e. group 45 (2-3). (Figs. 5.1, 5.2 & 5.3).

ii) Polyether/SS

Polyether and stainless steel differ significantly ($p < 0.05$) in all cases. (Figs. 5.2 & 5.4).

iii) Plaster/Polyether

Plaster and polyether differ significantly ($p < 0.05$) in all but three areas: i.e. groups 41 (1-2), 43 (1-4) and 50 (4-5). (Figs. 5.2 & 5.5).

The largest P-value (0.972) is found in group 43 (1-4) between plaster and polyether.

This indicates the least significant difference as can also be seen in the line graph in Figure 5.17 where the two lines are closely spaced.

In Figure 5.18 (group 44; 1-5) the plaster and polyether lines can be seen on either side of the stainless-steel line. Over this longest distance on the model it seems that the plaster impression has contracted and the polyether expanded relative to the SS model. Though there is still evidence of statistical significance observed in group 43, the one for Group 44 gives a more serious evidence of difference. Relatively therefore, observed difference in Group 43 is less than that for Group 44.

The chart below (Fig. 5.6) Discrepancy of Median Measurements of Impressions, indicates the discrepancy between the two impression materials compared to the stainless steel model.

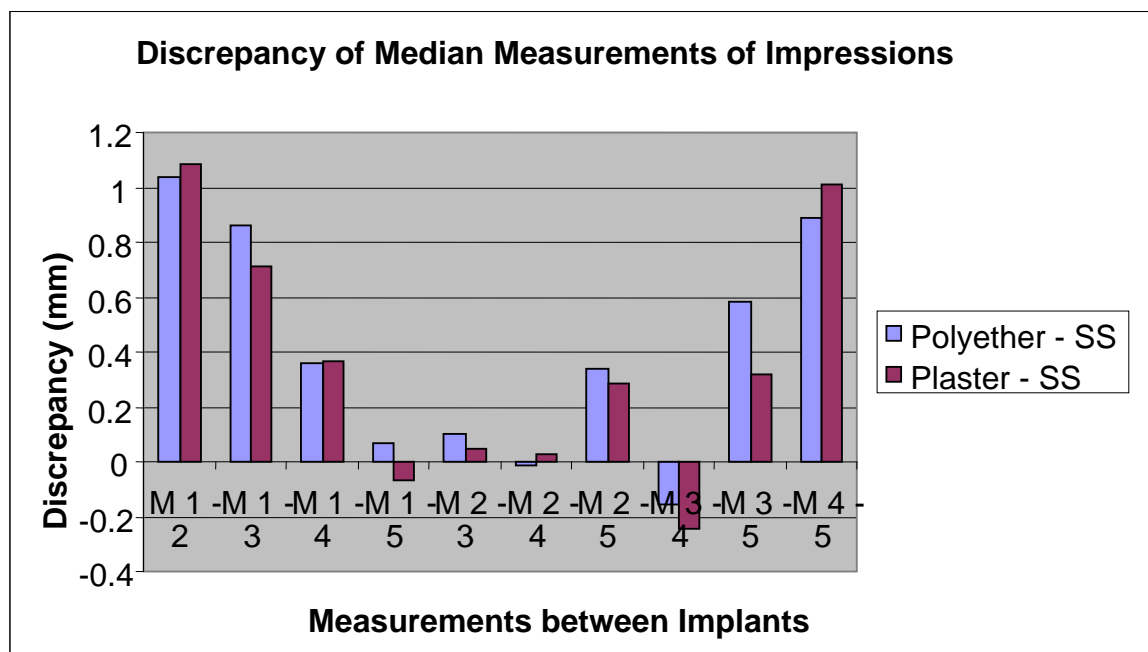


Fig. 5.6 Discrepancy of Median Measurements of Impressions

The width of the lines in Figure 5.7 reflects the magnitude of the discrepancy in relation to its position on the model.

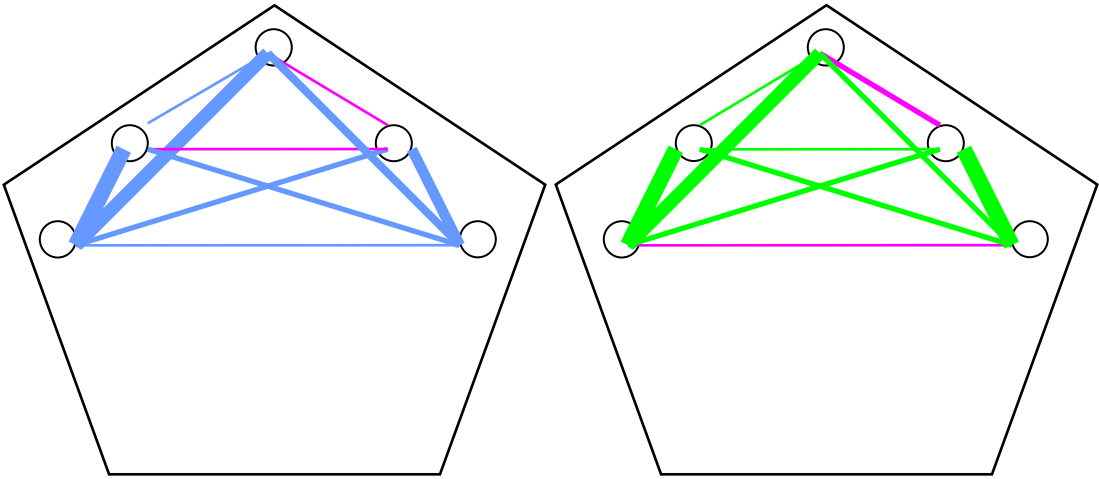


Fig 5.7 Magnitude of Discrepancy for Impressions

Polyether-SS	expansion	—	Plaster-SS	expansion	—
	contraction	—		contraction	—

B. Casts:

a) No significant difference ($p>0.05$) between:

Plaster/SS	▬
Polyether/SS	▬
Plaster/Polyether	▬▬▬▬

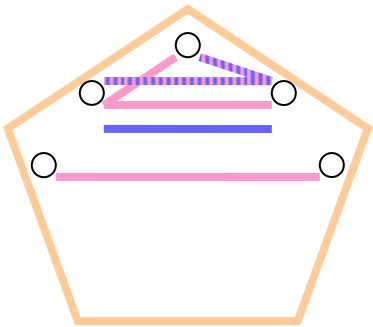


Fig. 5.8 No Significant diff: Casts

b) Significant difference ($p < 0.05$)

Significant differences were found in the following areas:

Plaster/SS

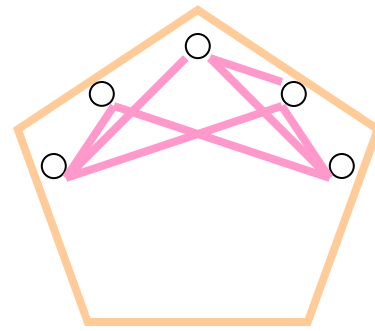


Fig. 5.9 Significant diff: Pl/SS

Polyether/SS

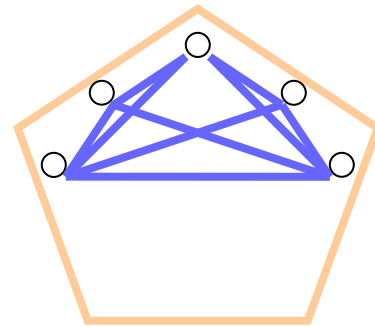


Fig. 5.10 Significant diff: Polyether/SS

Plaster/Polyether

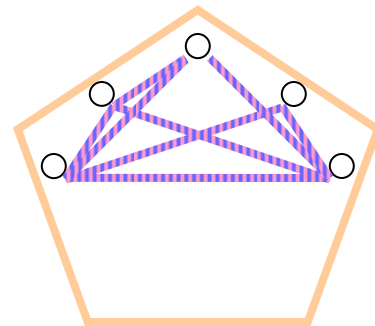


Fig. 5.11 Significant diff: Plaster/Polyether

i) Plaster/SS

Plaster and stainless steel differ significantly ($p < 0.05$) in all but three areas:

i.e. group 44 (1-5), 45 (2-3) and 46 (2-4). (Figs. 5.8 & 5.9).

ii) Polyether/SS

Polyether and stainless steel differ significantly ($p < 0.05$) in all but one area: i.e. group 46 (2-4). (Figs. 5.8 & 5.10).

iii) Plaster/Polyether

Plaster and polyether differ significantly ($p < 0.05$) in all but two areas: i.e. group 46 (2-4) and 48 (3-4). (Figs. 5.8 & 5.11.)

The line graphs for group 46 (2-4) (Fig. 5.30) and group 48 (3-4) (Fig. 5.32) are the only graphs where the values for the polyether casts are smaller than the stainless steel model (contractive distortion). In all the other graphs both the polyether and plaster lines lie above the stainless steel line, depicting expansive distortion, with polyether casts having a larger degree of expansive distortion than plaster casts.

This contraction for (2-4) and (3-4) is also depicted in Fig. 5.12 Discrepancy of Median Measurements of Casts. The discrepancy between the casts of the two impression materials compared to the stainless steel model is illustrated in the graph below (Fig. 5.12).

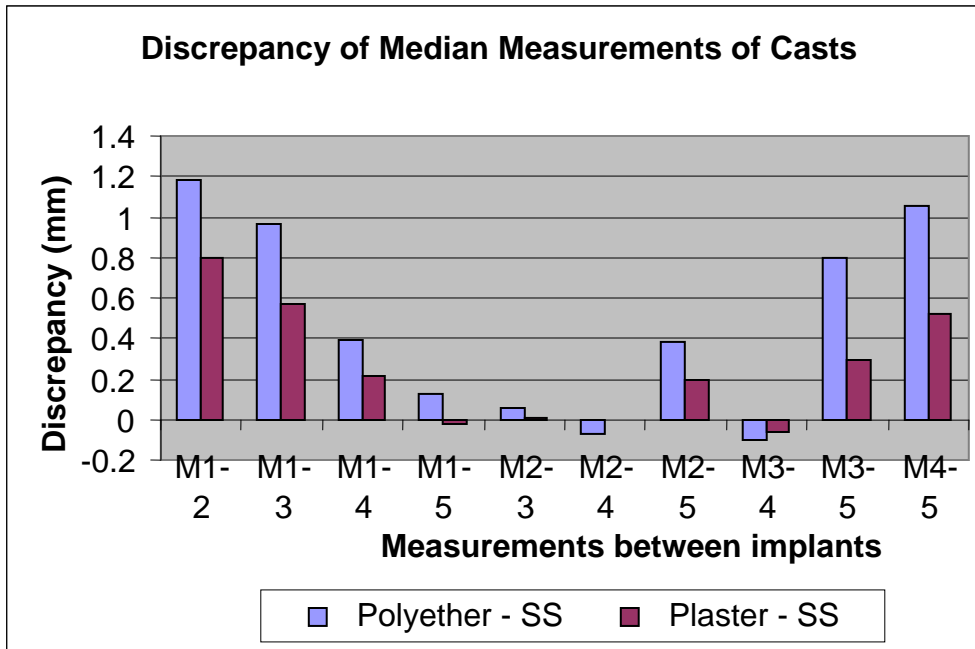


Fig. 5.12 Discrepancy of Median Measurements of Casts

The weight of the lines in Fig 5.13 reflect the magnitude of the discrepancy in relation to its position on the model.

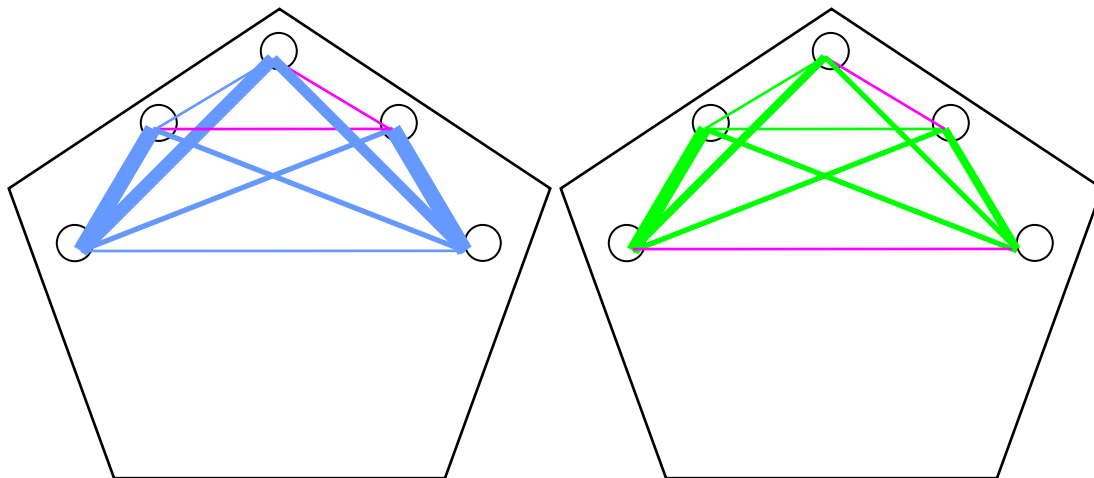


Fig. 5.13 Magnitude of Discrepancy for Casts

Polyether-SS	expansion	—	Plaster-S	expansion	—
	contraction	—		contraction	—

F-value

The F-value it is another statistical test to determine significance.

Definition of F value: The ANOVA procedure employs the statistic (F) to test the statistical significance of the differences among the obtained means of two or more random samples from a given population. Using the Central Limit Theorem, one calculates two estimates of a population variance.

(1). An estimate in which the s square of the obtained means of the several samples is multiplied by n (the size of the samples).

(2). An estimate that is calculated as the average (mean) of the obtained s squares of the several samples.

The statistic value (F) is formed as the ratio of (1) over (2). If this ratio is sufficiently larger than 1.0, the observed differences among the obtained means are described as being statistically significant.

For the casts, all 10 groups have fairly high F values (ranging from 9.69 to 1282.07) except for group 46 which has a value of less than 1 (0.51). The large F values indicate that the plaster and polyether impression materials do provide significant differences in the casts that they produce. The exception is group 46. (Implant 2-4)

Total Inter-Implant Distances

The following table (5.1) depicts the Total Distances when the 10 various distances (mean values) are added together.

Table 5.1 Total of Mean Distances (mm)

	Polyether	Plaster	S-Steel
Impressions	282.90	282.10	278.74
Casts	284.04	281.31	278.74

From these values were calculated the differences and the percentage of expansion compared to the stainless-steel model as shown in table 5.2. It is noticeable that for the resultant casts the percentage expansion for polyether is double that of plaster.

Table 5.2 Expansion relative to Stainless-steel

	Polyether: mm	% exp Polyether	Plaster: mm	% exp Plaster
Impressions	4.17	1.49	3.37	1.21
Casts	5.30	1.90	2.57	0.92

The chart below of Total of Mean Inter-implant Distances (Fig. 5.14) reflects the sum of all the mean individual inter-implant measurements.

This shows over the total distances that casts from polyether showed more expansive distortion than casts from plaster. In fact, the casts from plaster underwent contraction in relation to their impressions.

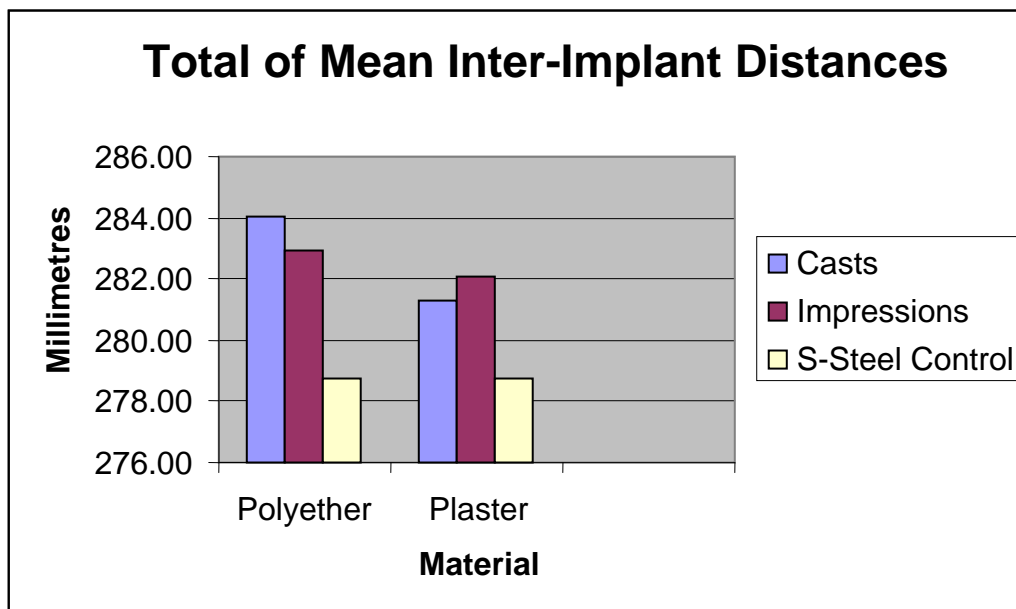


Fig 5.14 Total of Mean Inter-Implant Distances

CHARTS: COMPARISON OF IMPRESSIONS AND S-STEEL

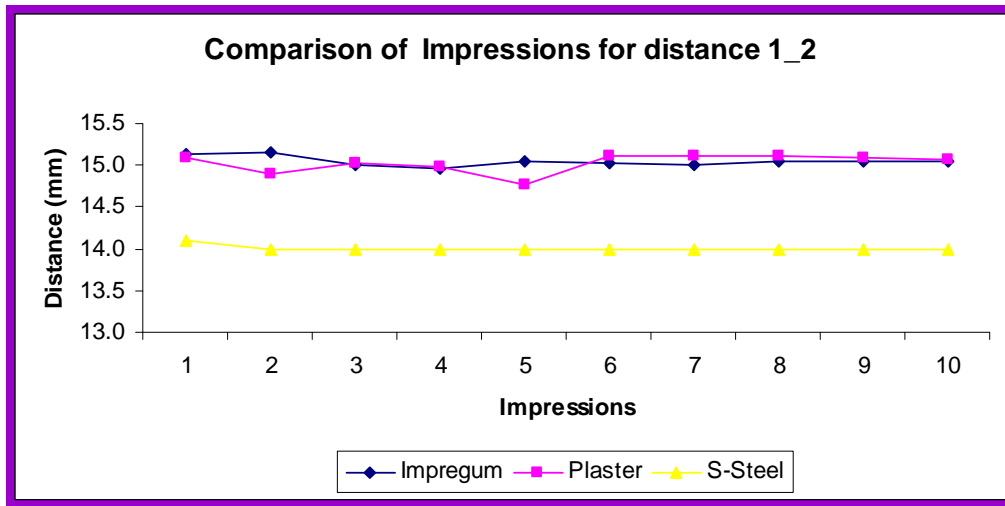


Fig.5.15

Group 41

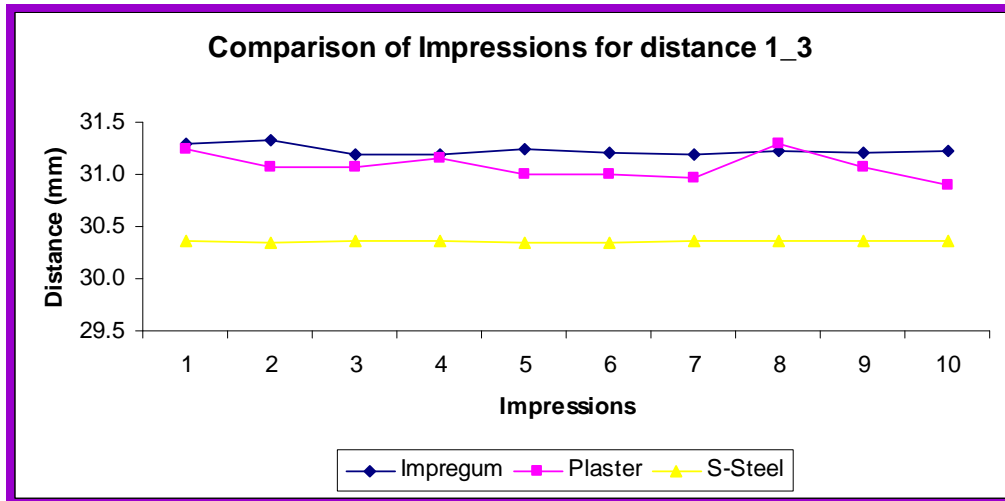


Fig.5.16

Group 42

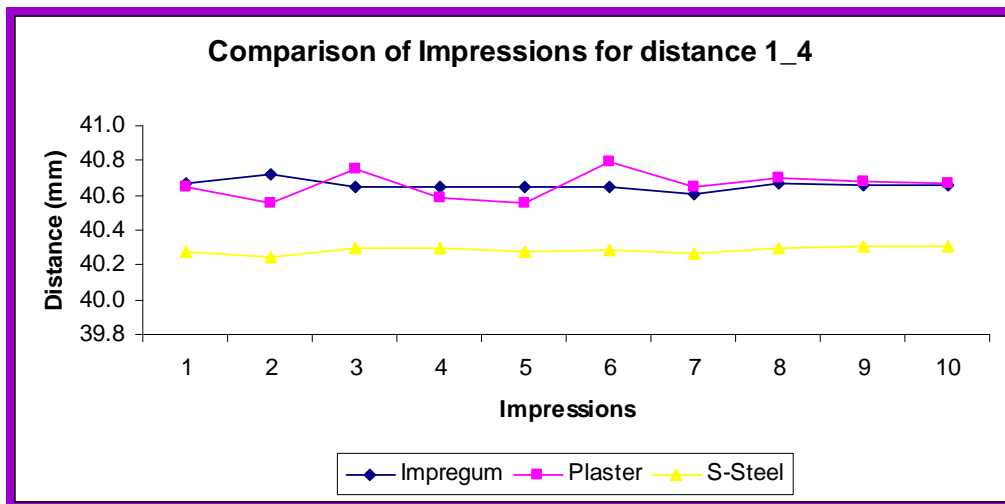


Fig.5.17

Group 43

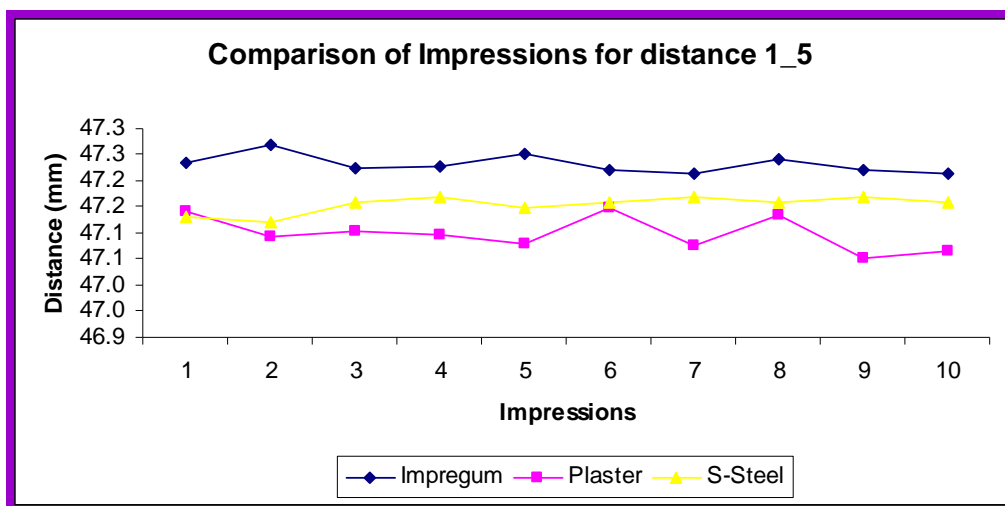


Fig.5.18 Group 44

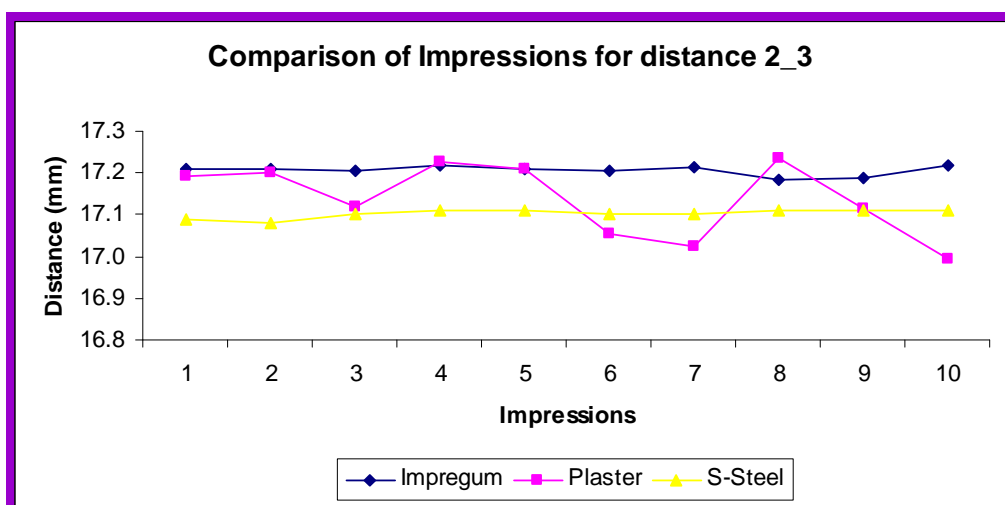


Fig.5.19 Group 45

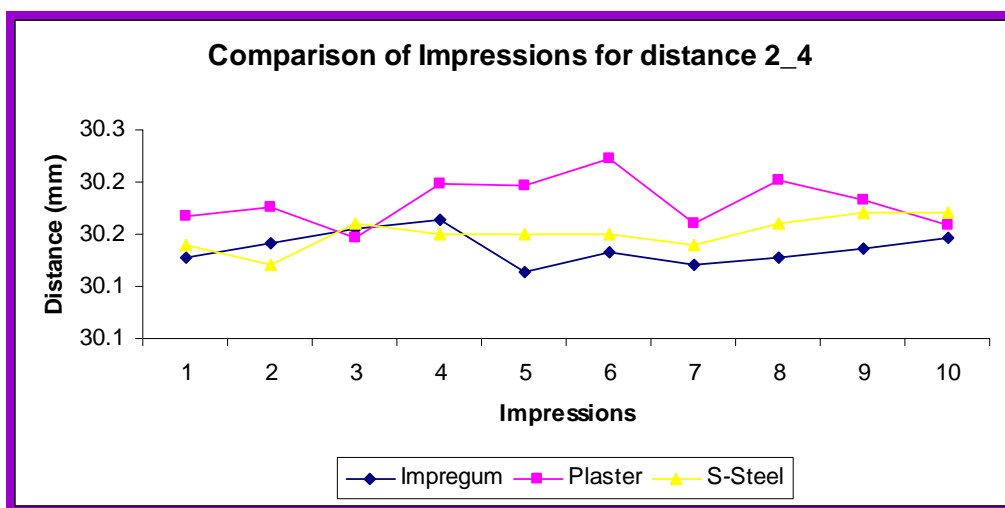


Fig.5.20 Group 46

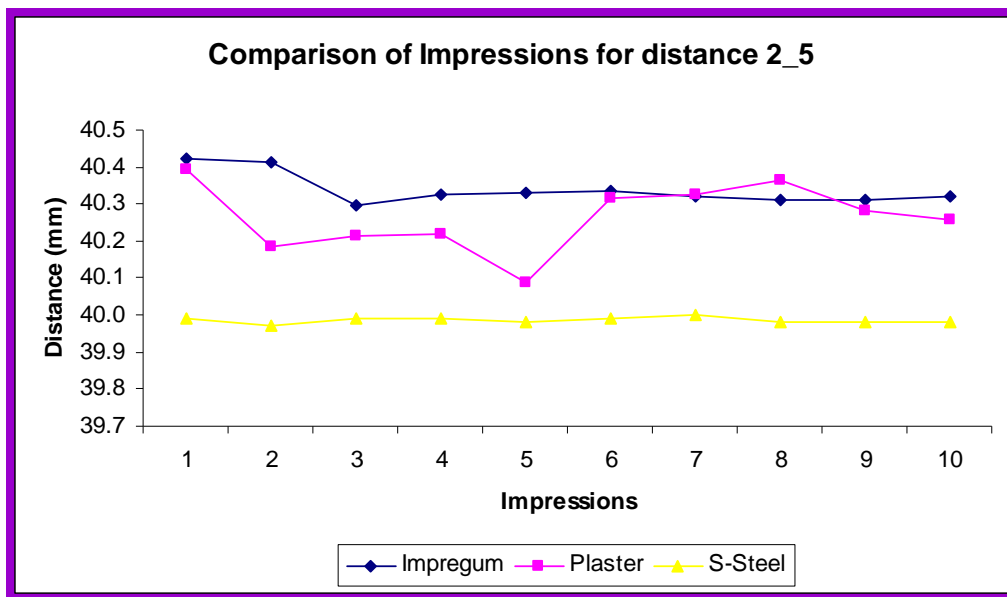


Fig.5.21 Group 47

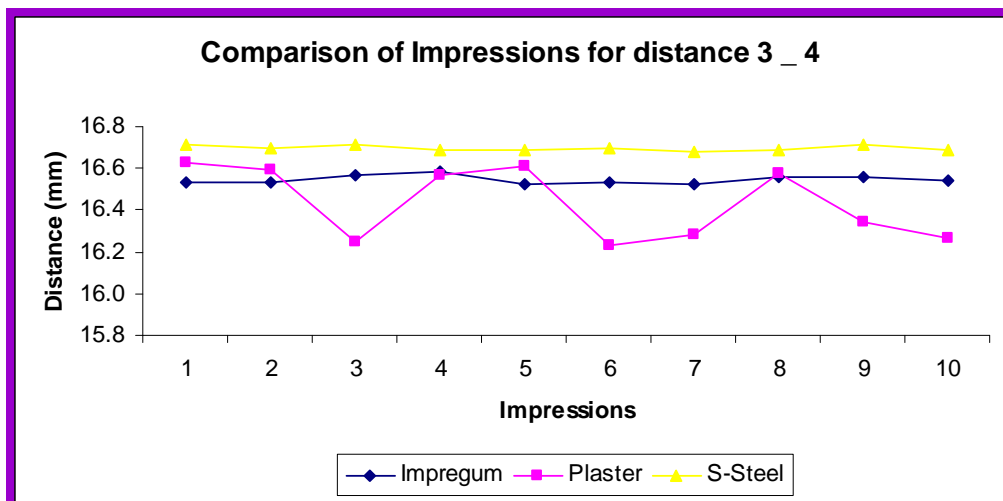


Fig.5.22 Group 48

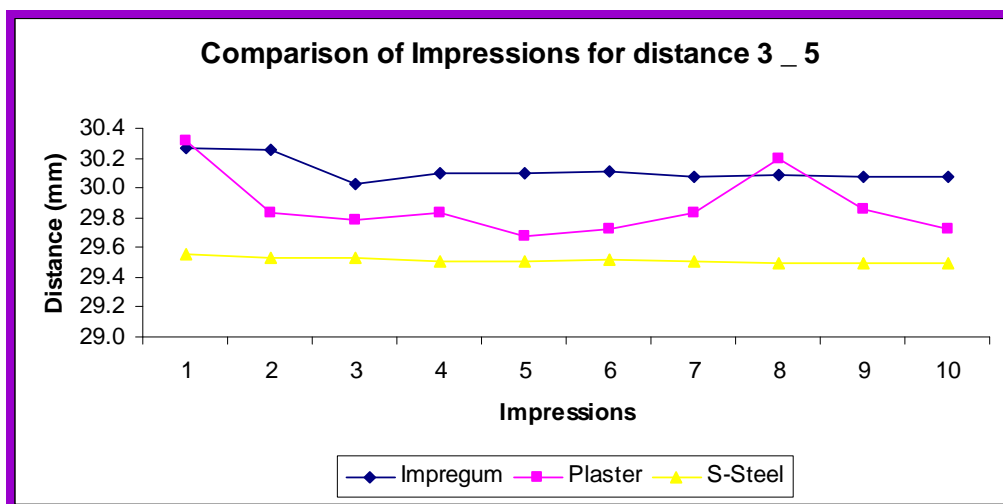


Fig.5.23 Group 49

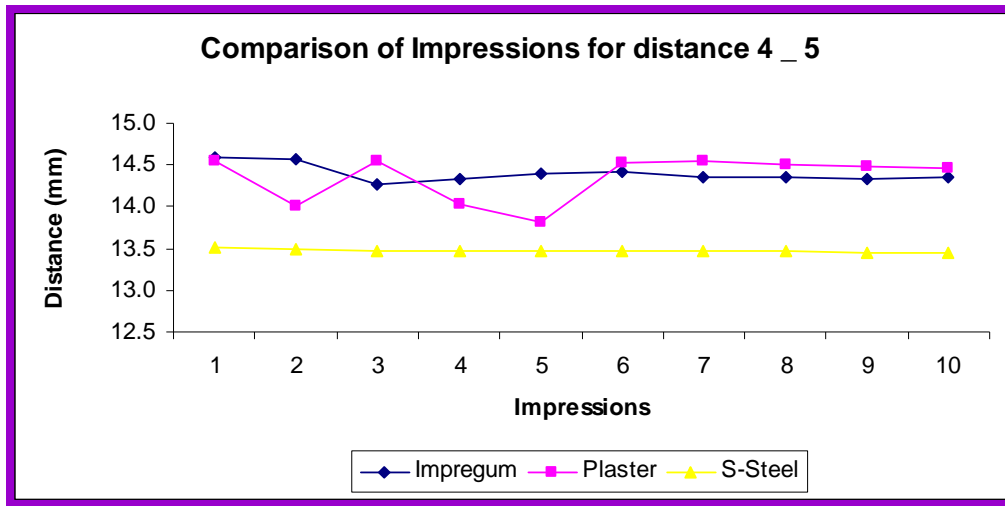


Fig.5.24

Group 50

CHARTS: COMPARISON OF CASTS AND S-STEEL

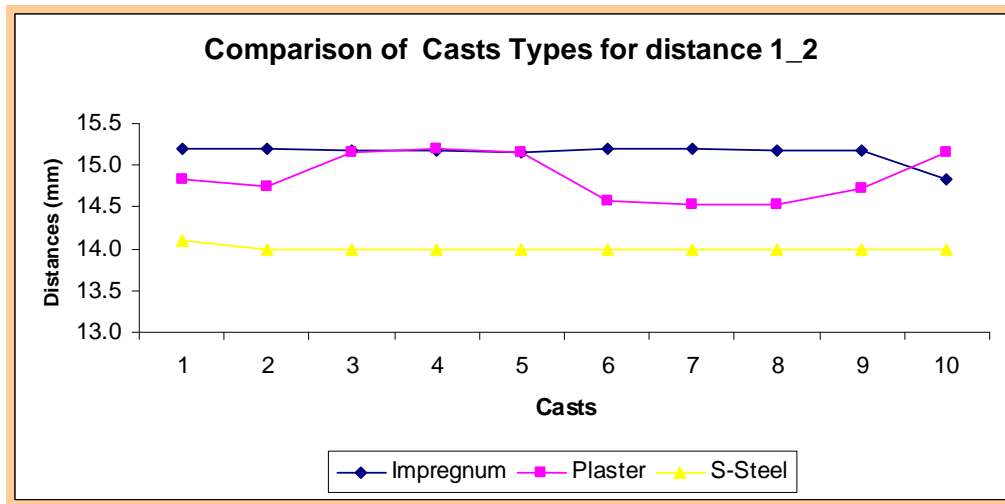


Fig.5.25 Group 41

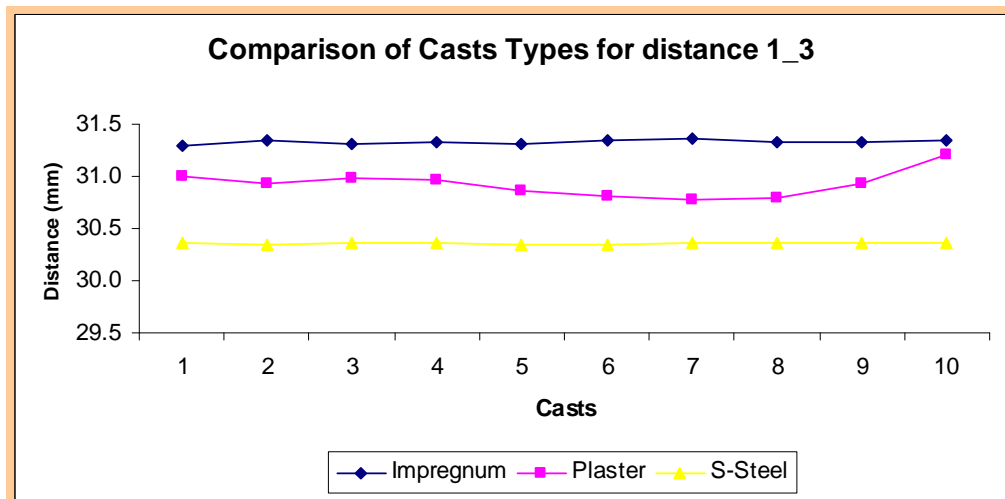


Fig.5.26 Group 42

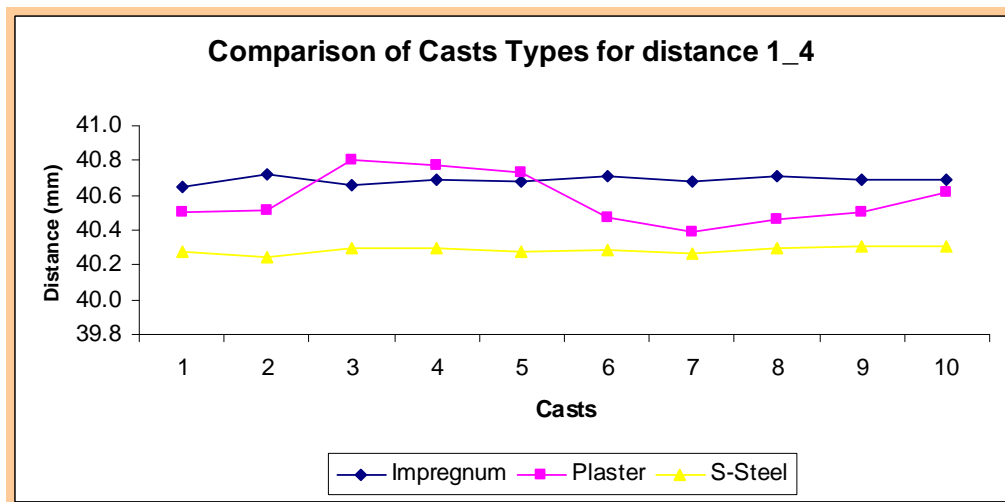


Fig.5.27 Group 43

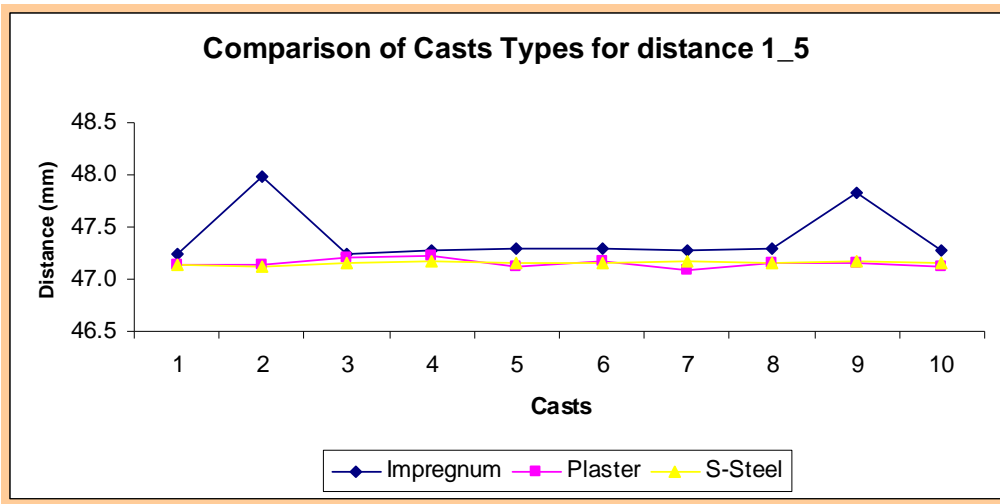


Fig.5.28 Group 44

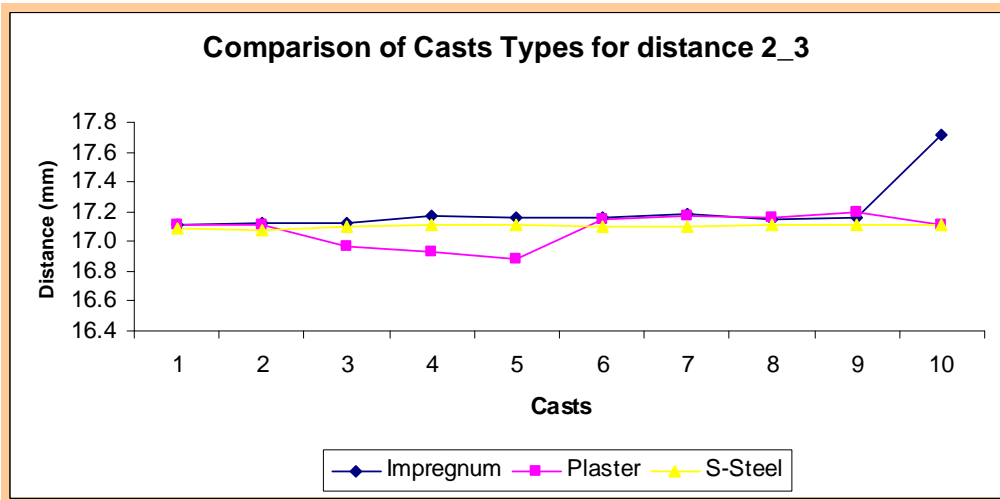


Fig.5.29 Group 45

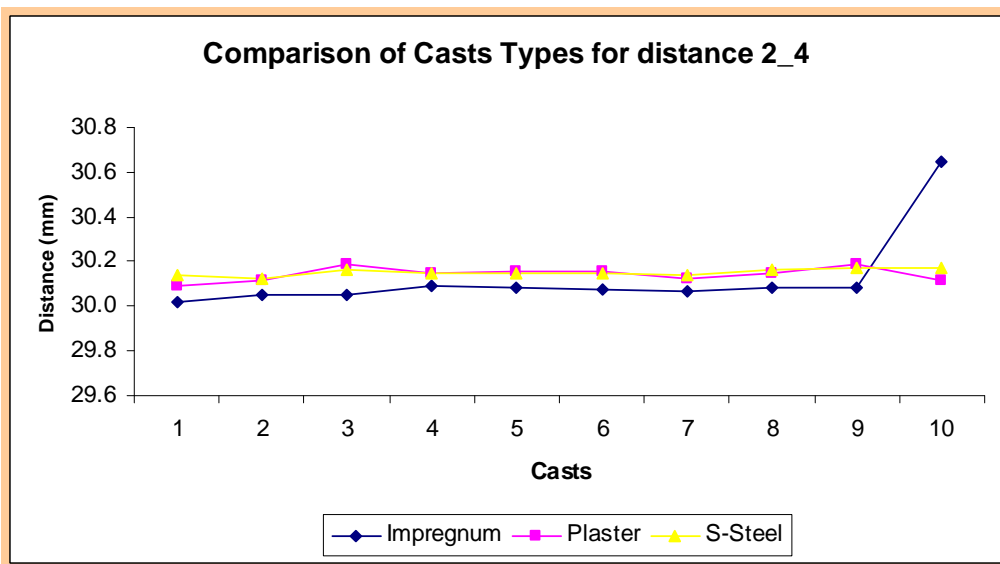


Fig.5.30 Group 46

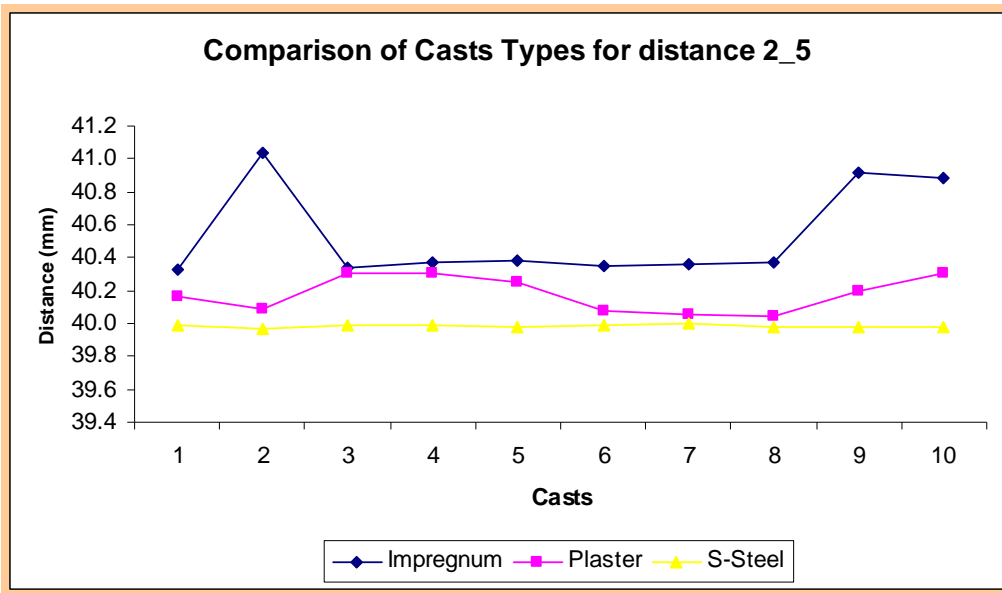


Fig.5.31 Group 47

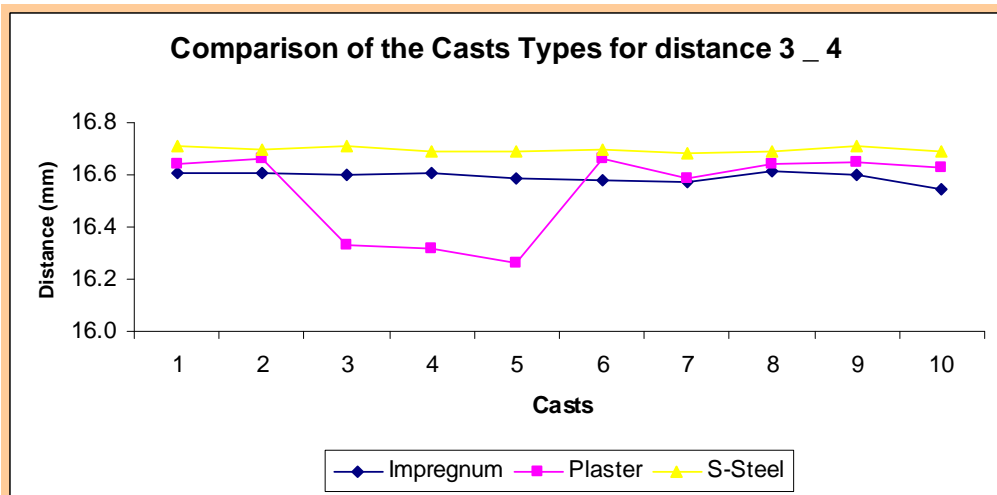


Fig.5.32 Group 48

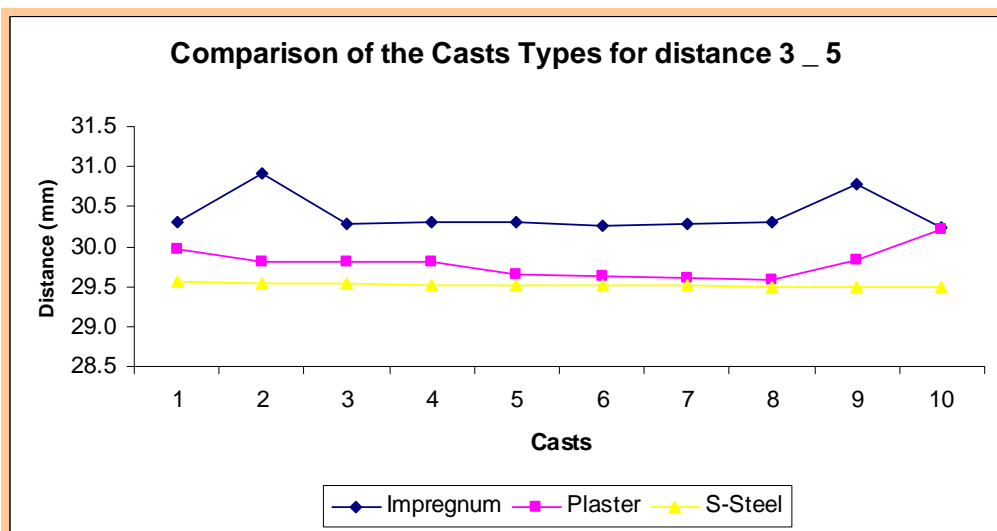


Fig.5.33 Group 49

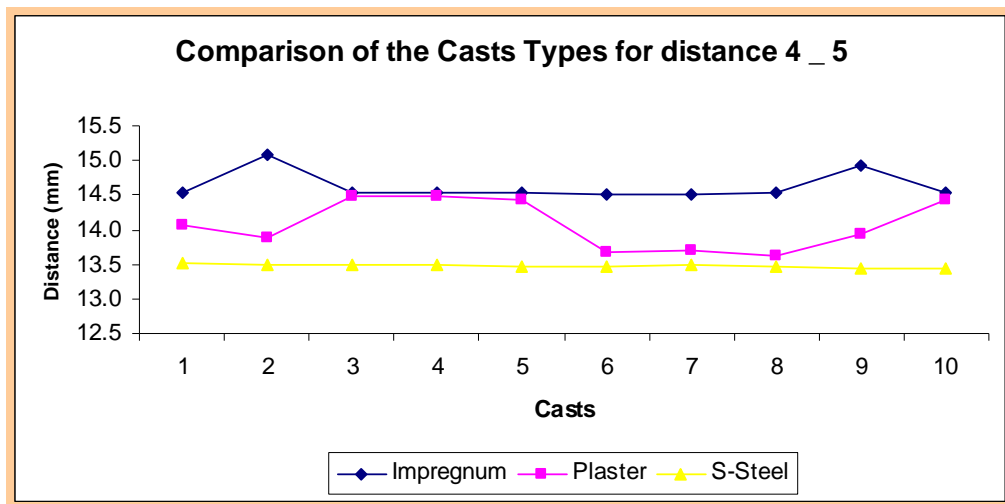


Fig.5.34

Group 50

COMBINED BOX PLOTS WITH SIGNIFICANCE INDICATION

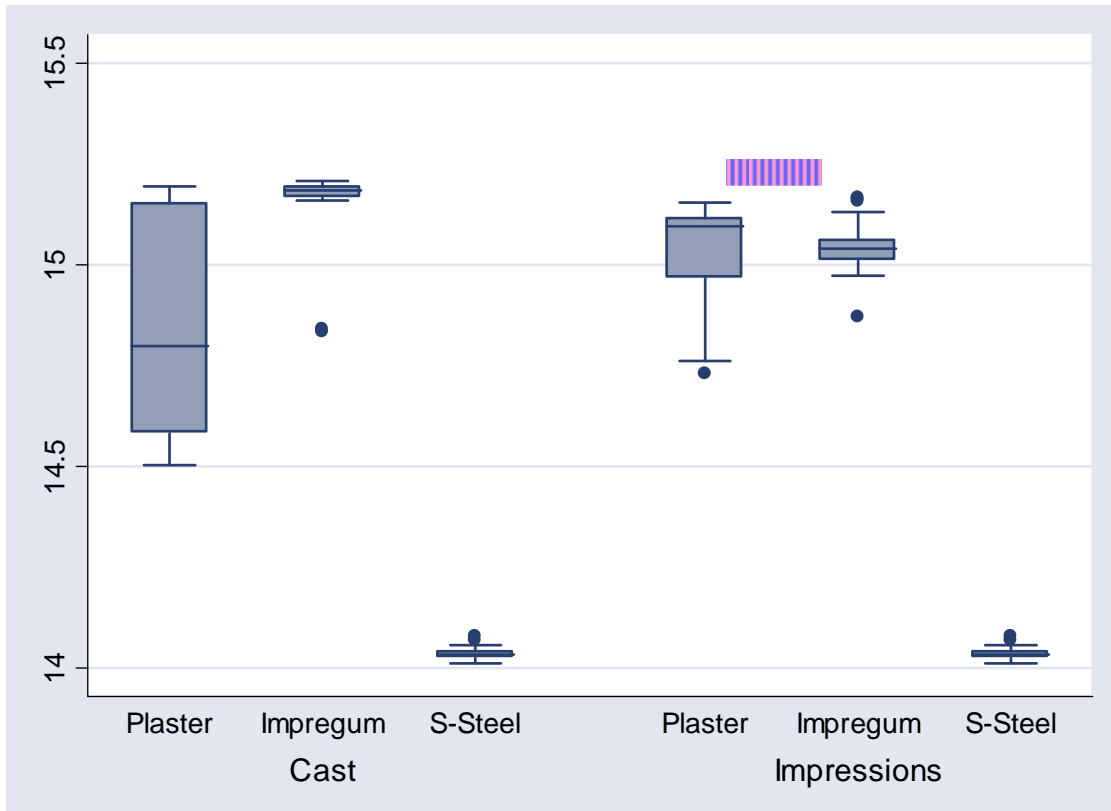


Fig. 5.35 Group 41 (1-2) in mm

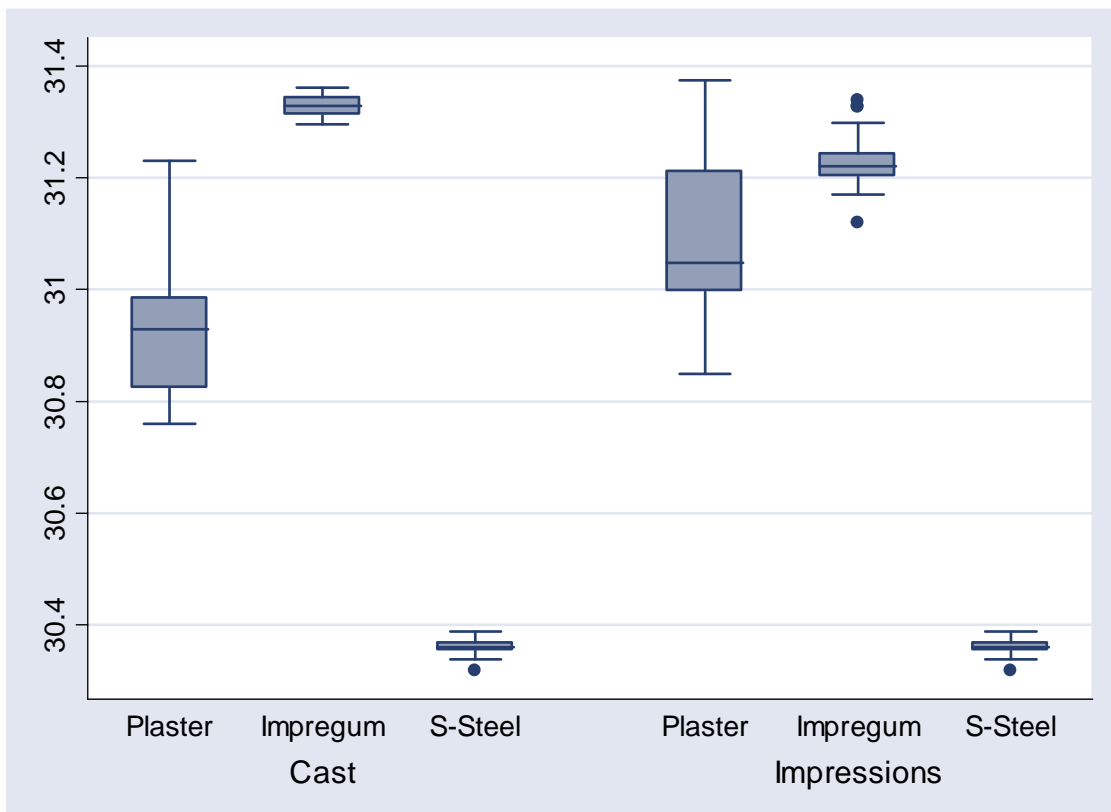


Fig. 5.36 Group 42 (1-3) in mm

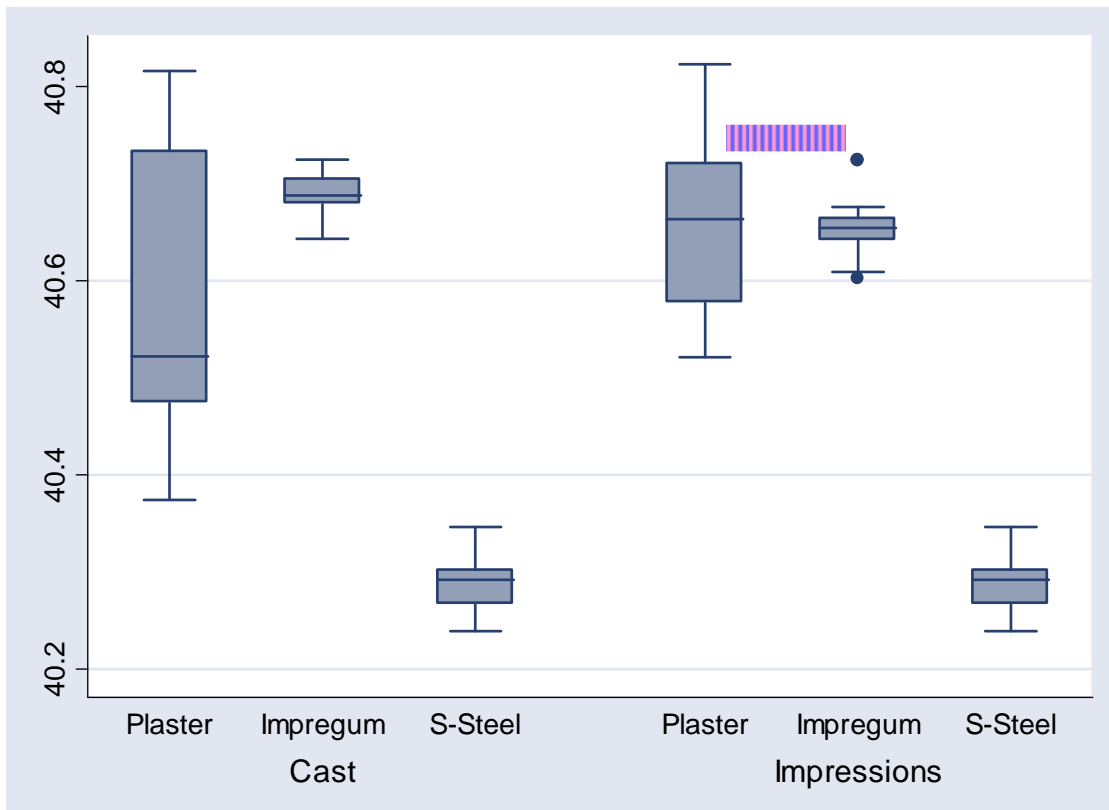


Fig. 5.37 Group 43 (1-4) in mm

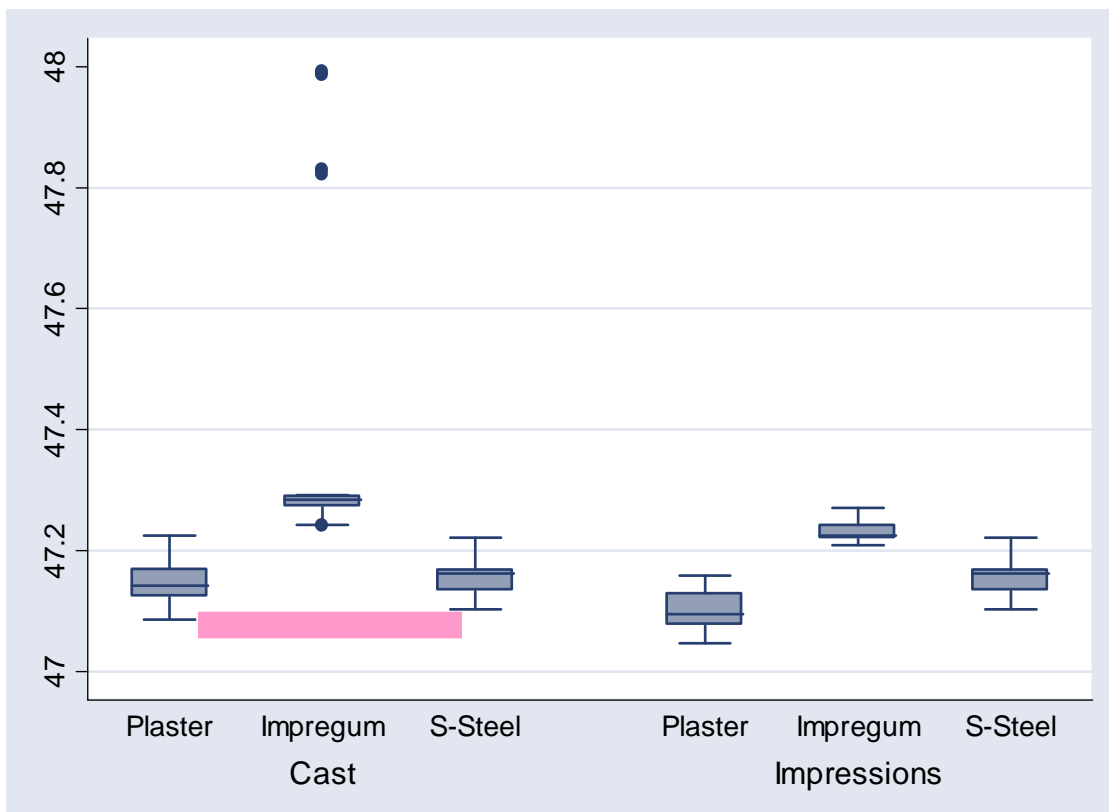


Fig. 5.38 Group 44 (1-5) in mm

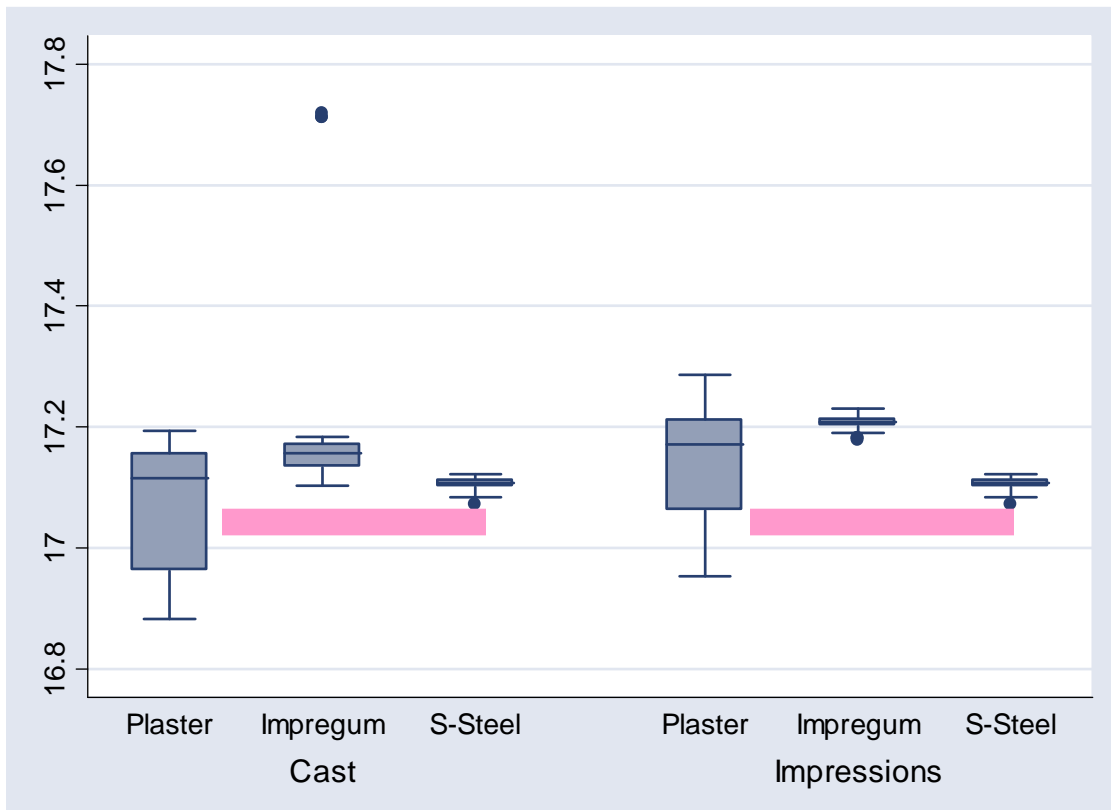


Fig. 5.39 Group 45 (2-3) in mm

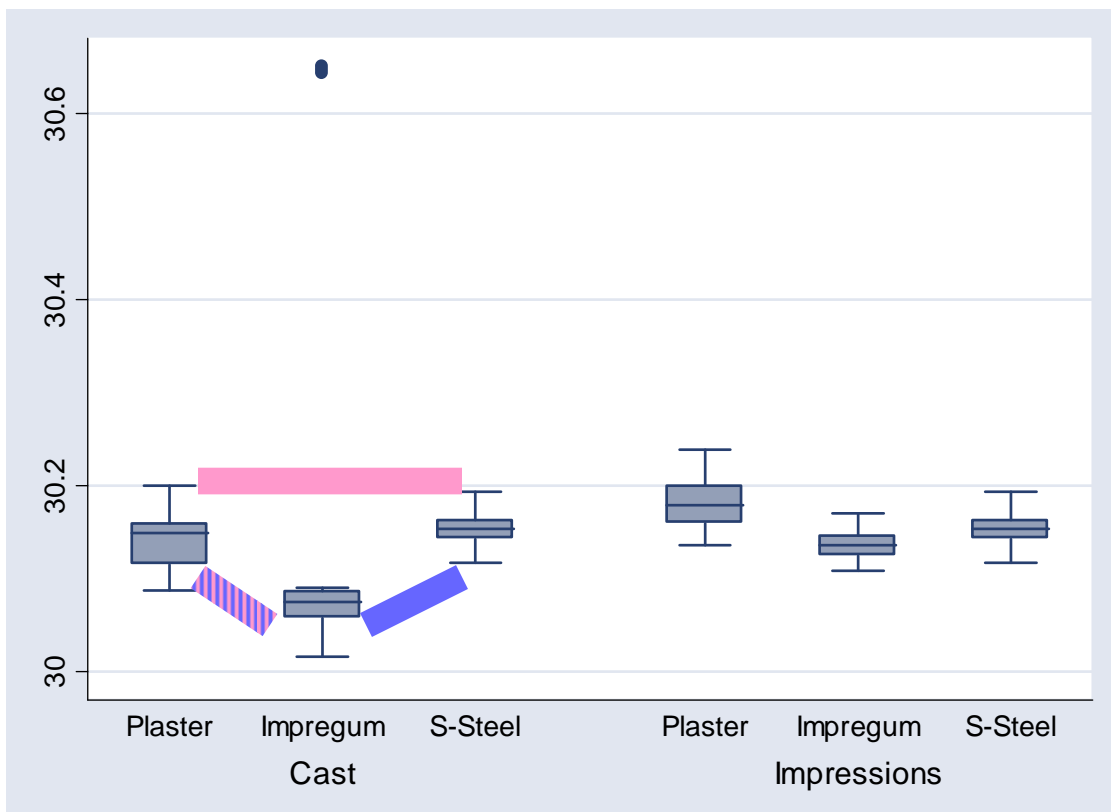


Fig. 5.40 Group 46 (2-4) in mm

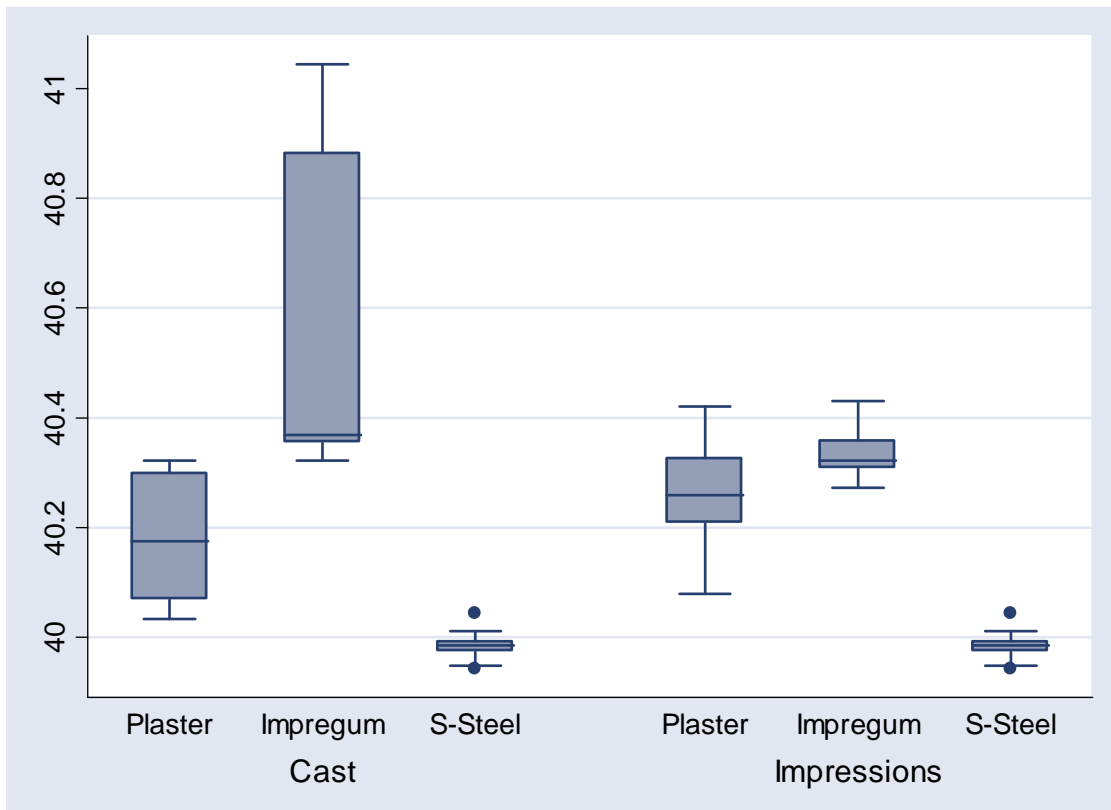


Fig. 5.41 Group 47 (2-5) in mm

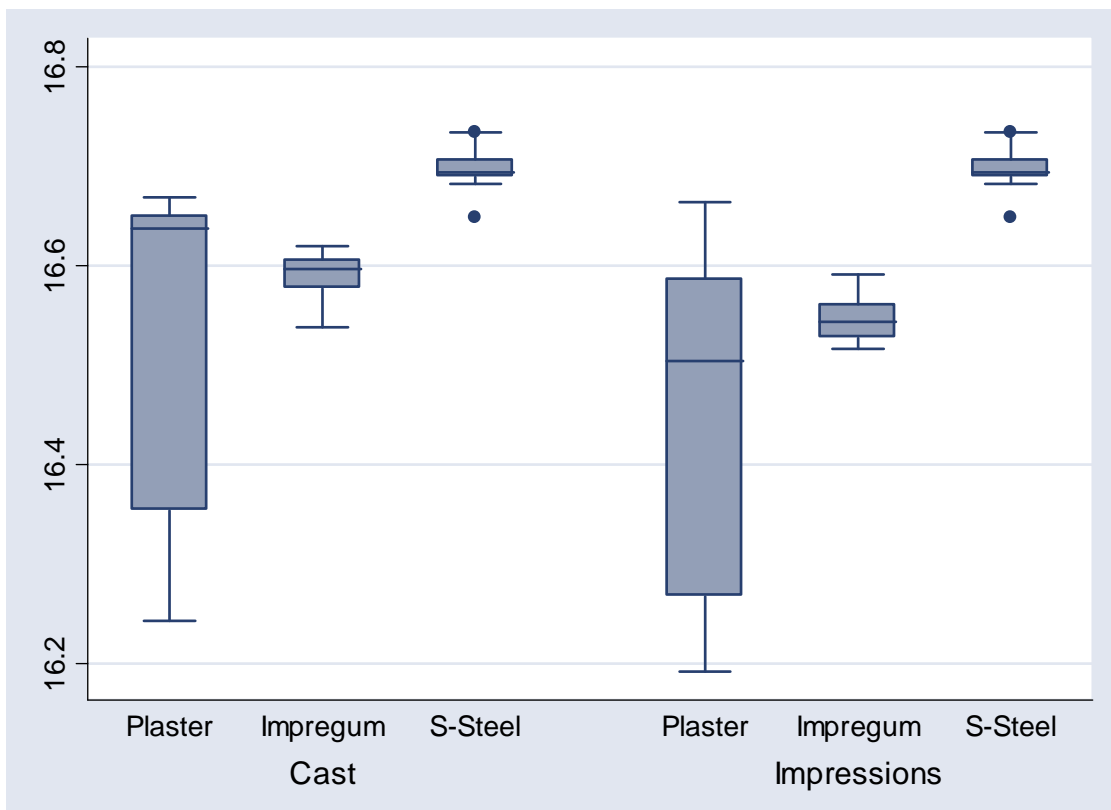


Fig. 5.42 Group 48 (3-4) in mm

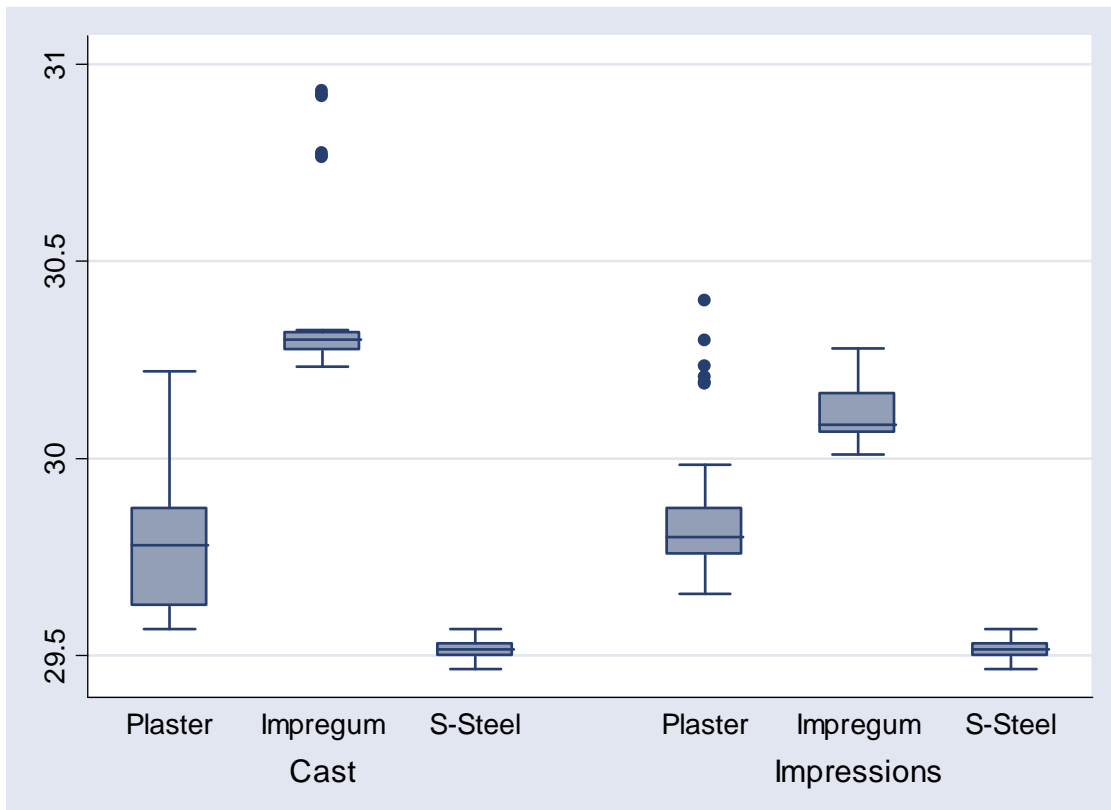


Fig. 5.43 Group 49 (3-5) in mm

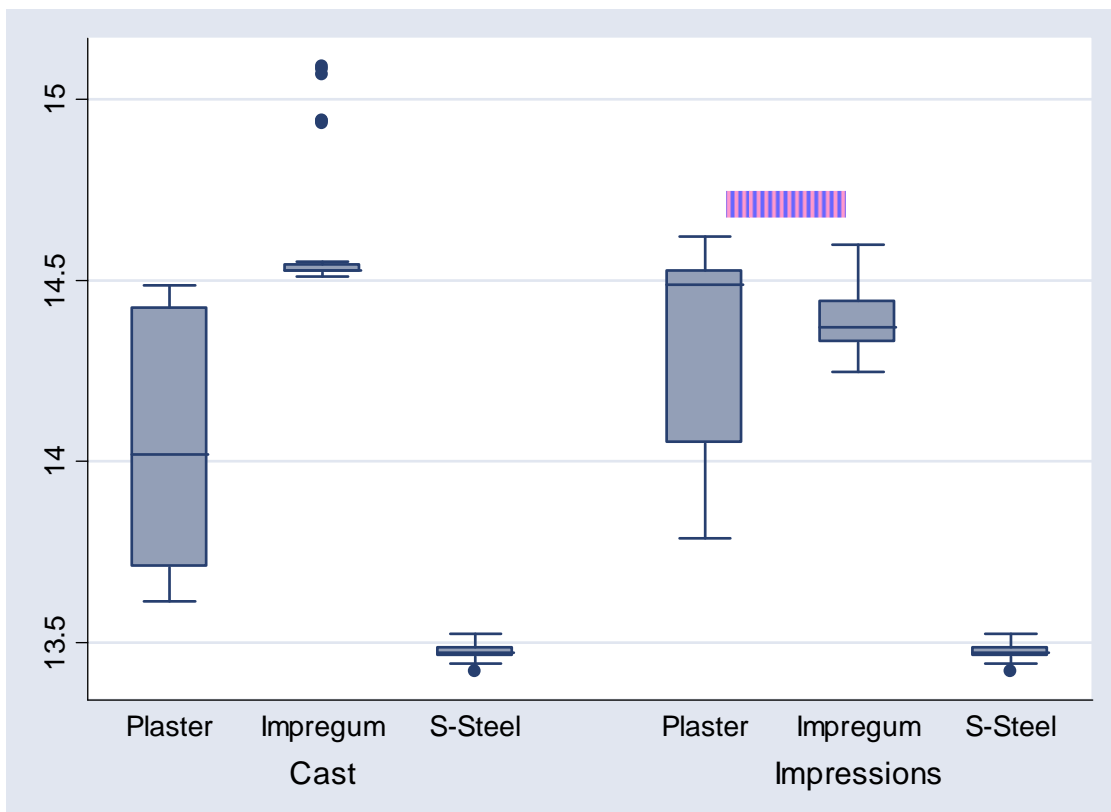


Fig. 5.44 Group 50 (4-5) in mm

6. DISCUSSION

The three-dimensional accuracy of two impression materials was investigated with the use of a Reflex Microscope. By studying the results a few observations were made.

It is not possible to make an undistorted impression or cast. These measurements and the review of the literature shows that it is almost impossible to duplicate the three dimensions from the jaw onto a cast on which a precisely fitting and passive superstructure can be manufactured. It appears from this set of results that horizontal dimensions between implant analogues tend to increase with both impression materials. This supports the findings of Linke et al.³². The rationale for using plaster impression material is the limitation of expansive distortion that takes place compared to polyether impressions. The general conclusion from these findings is that plaster creates less distortion, but that the reproduction of consistent dimensions is less predictable. The polyether measurements produced a straighter line graph, showing a better consistency over the ten models, but greater distortion.

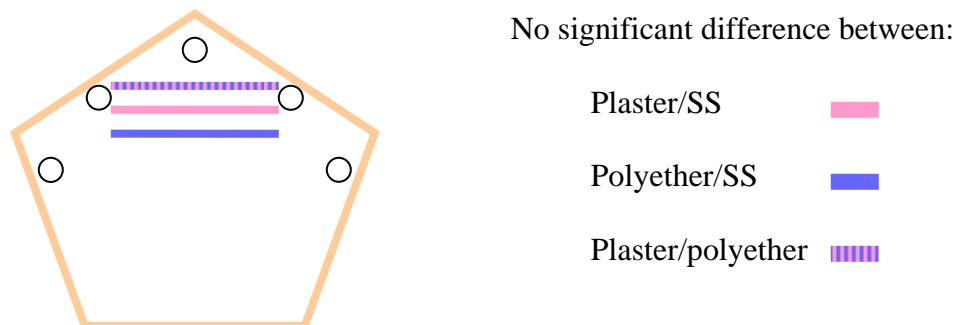


Fig. 6.1 Casts vs S-Steel

Distance 2-4 is the only distance where there is no significant difference for both casts and the master model (Fig. 6.1).

It is essential to have meticulous inspection of laboratory and clinical components during their connection, to prevent avoidable errors in fit which are not inherent to the impression, or laboratory techniques. When looking at the impressions under the Reflex Microscope, the author noticed several fibre or dust-like particles on the impression copings in the plaster impressions. These had to be removed with high pressure air spray before the implant analogues could be connected to the copings. These particles might have flaked off from the plaster and could make a meaningful difference in the vertical position of the analogue when secured over the debris.

Distortion is unpredictable and is determined by the site (Figs 5.12 & 5.13). It is likely to be expansive and more so in the anterior-posterior dimension than in a lateral dimension. From Fig. 5.12 it is noticeable that the differences in measurements across the model are negligible. The differences in measurements anterior-posteriorly are much bigger; almost 1 .2 mm for polyether casts from distance 1-2. This may possibly result in a framework that is wide enough but too long in the anterior-posterior dimension. Contraction distortion during the process was found to be less than the expansive distortion resulting in net expansion.

The least distortion appears generally to be across the cast. In this case it included the tilted implants. Group 46 (2-4) recorded a P-value of 0.955 which indicates a non-significant difference between the casts from plaster and the S-Steel model. This was the second highest P-value recorded for casts. The highest was 0.996 also for

casts from plaster vs. S-S for group 44 (1-5), indicating the least significance of all measurements. Both measurements were across the cast.

The casts from polyether were generally bigger than their impressions (Fig 5.15) by a magnitude of 1.14mm over the total distance measured (284.04mm for the casts vs. 282.90mm for their impressions)(Table 5.1). That is an expansion of 0.4%. Over the same distance measured the casts from polyether were 5.3mm bigger than the stainless steel model. That is a 1.9% expansion (Table5.2).

The casts from plaster, however, were smaller than their impressions by 0.79mm over the total distance (281.31mm for the casts vs. 282.10mm for their impressions). That is shrinkage of 0.28%. The casts from plaster were still larger than the stainless steel model by 2.57mm which is expansion of 0.92%. From this it appears that the amount of expansion for polyether casts is double that of plaster casts which may be significant in the passive fit of the framework.

As a result of the discrepancies that occur using stone casts, current research and development is being directed towards techniques that eliminated them from the fabrication of the prosthesis. The importance of that is to eliminate the sectioning and luting of the metal framework and thereby having to alter the working model.

Sectioning and reassembling the framework is time-consuming and results in a weaker and metallurgically more complex prosthetic framework. The CAD/CAM technique may full-fill this requirement. Images are scanned intraorally or extra orally and frameworks are manufactured from this information. The Procera implant bridge works on this technique. The problem here is that a distorted model is scanned which

defeats the object. Ideally the implants should be scanned intraorally, but currently that is a technique which is not yet available.

Passive abutments are components which may be used in cases where a passive fit cannot be established (Fig. 6.2). With an ill-fitting framework passive abutments can be secured over the implants with a small screw. The framework is subsequently cemented onto the passive abutments. Due to the tolerances that exist, the leeway is taken up by cement. Once the cement has set the small screws are removed and the passive abutments will be picked up by the framework. The whole framework can now be secured onto the implants with the bigger screws. This allows the framework to be screw-retained while discrepancies are absorbed in the cement (Fig.6.3).

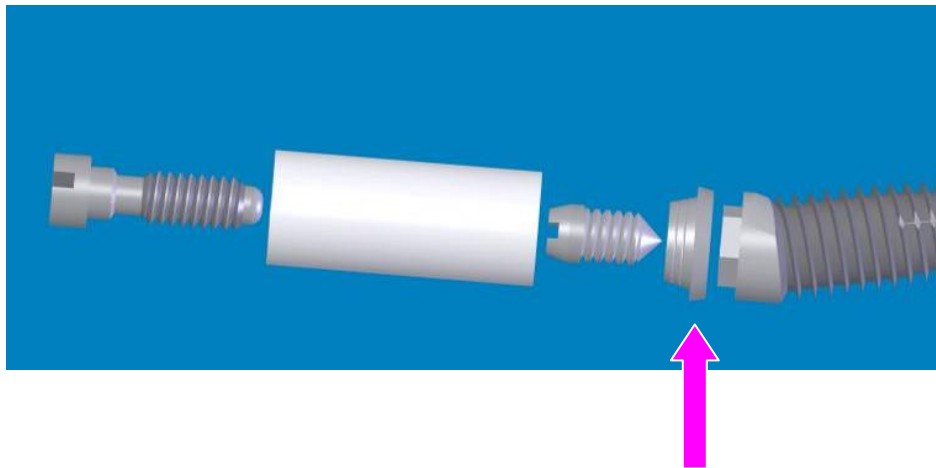


Fig. 6.2 the Passive abutment

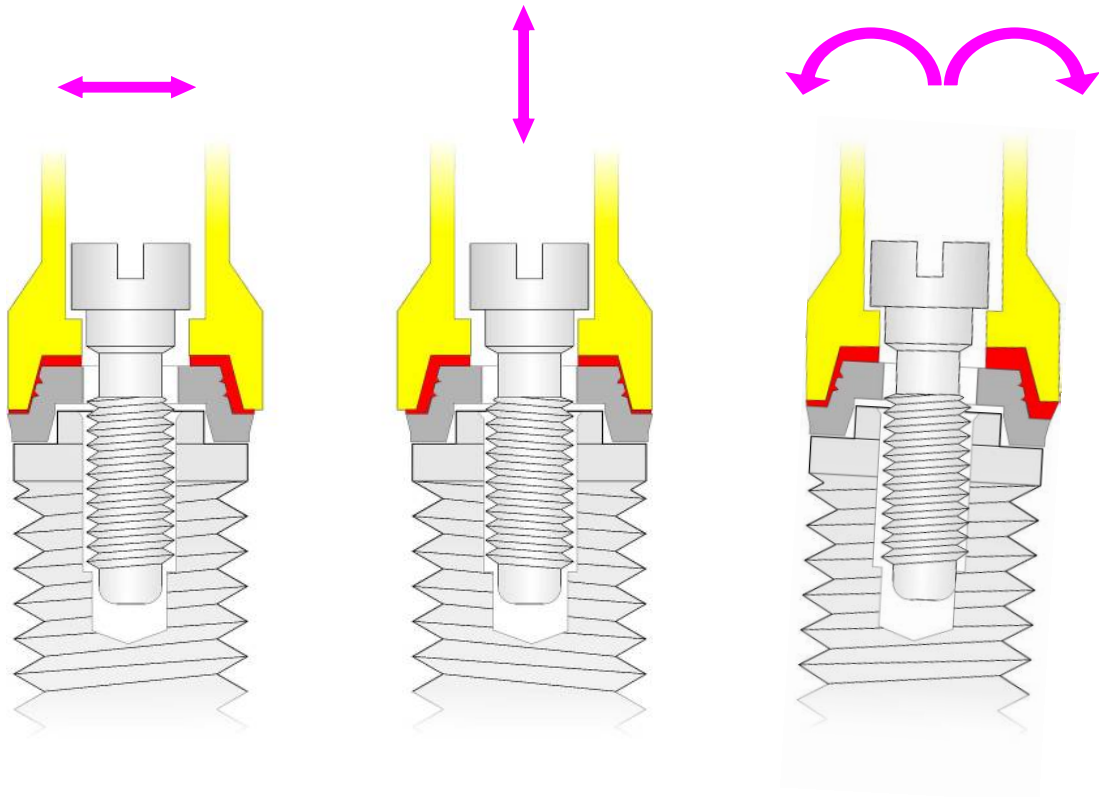


Fig. 6.3 Diagram of passive abutment illustrating its capacity to allow ill-fitting frameworks to be adapted to the implants.

Gallucci et al.⁵⁶ immediately loaded implants with a provisional restoration in order to minimise "micromotion". In this way, fibrous encapsulation is prevented, and osseointegration results. When the provisional restoration was removed on a fortnightly basis, screw loosening was found in all patients after the first removal of the prosthesis, but no screw loosening was found 15 days later. It appears that, if the implants are splinted with no tension on them, the normal complications with ill-fitting prostheses are prevented. However, Jemt and Book⁵ disagree, and state that no orthodontic adjustment takes place around osseointegrated implants with stress introduced on them. Hoshaw, Brunski and Cochran⁵⁷ concluded that there was an

increased bone modelling response at the periosteal surface near loaded implants.

Further study in this field is necessary.

7. CONCLUSION

Under the conditions of this study the following conclusions can be drawn with respect to distortion of implant analogue positions on the master cast:

1. The null hypothesis is rejected as there is a significant difference between models made using polyether impression material compared to those made with plaster impression material.
2. Plaster impression material results in less expansion of the cast, but in more variance with less predictability.
3. As a result of this finding, plaster impression material should be considered for full arch implant supported prostheses.
4. Digital intraoral scanning of the implants may be the future solution for more accurate reproduction of implant positions.
5. A plaster free technique may be considered where a passive cementation matrix is used. The cementation matrix is screwed onto the implants, luted together and taken off. Implant analogues are connected to the cementation matrix and attached to each other without using plaster. Theoretically no distortion takes place.

8. APPENDIX A TABLE OF MEANS IMPRESSIONS

```
. anova distance type model type* model if group==41
```

```
Number of obs =      90      R-squared      = 0.9938
Root MSE      = .046197      Adj R-squared = 0.9908
```

Source	Partial SS	df	MS	F	Prob > F
Model	20.5522996	29	.708699986	332.08	0.0000
type	20.104063	2	10.0520315	4710.10	0.0000
model	.145838885	9	.016204321	7.59	0.0000
type*model	.302397676	18	.016799871	7.87	0.0000
Residual	.128048584	60	.002134143		
Total	20.6803482	89	.232363463		

```
. table type model if group==41, c(mean distance n distance sd distance) format(%7.2f)
```

typelbl	model									
	1	2	3	4	5	6	7	8	9	10
Impregum	15.12 3 0.01	15.16 3 0.00	15.00 3 0.02	14.96 3 0.08	15.04 3 0.02	15.03 3 0.02	15.00 3 0.02	15.05 3 0.01	15.05 3 0.05	15.04 3 0.01
Plaster	15.10 3 0.01	14.90 3 0.14	15.04 3 0.09	14.99 3 0.14	14.77 3 0.05	15.12 3 0.00	15.11 3 0.01	15.12 3 0.01	15.10 3 0.00	15.07 3 0.00
S-Steel	14.07 3 0.01	14.04 3 0.02	14.05 3 0.01	14.03 3 0.01	14.02 3 0.01	14.03 3 0.00	14.03 3 0.01	14.03 3 0.00	14.03 3 0.01	14.03 3 0.01

```
. anova distance type model type* model if group==42
```

```
Number of obs =      90      R-squared      = 0.9903
Root MSE      = .046811      Adj R-squared = 0.9856
```

Source	Partial SS	df	MS	F	Prob > F
Model	13.4156254	29	.462607771	211.11	0.0000
type	12.9399282	2	6.46996408	2952.61	0.0000
model	.185396713	9	.020599635	9.40	0.0000
type*model	.29030049	18	.016127805	7.36	0.0000
Residual	.131475971	60	.002191266		
Total	13.5471013	89	.152214622		

```
. table type model if group==42, c(mean distance n distance sd distance) format(%7.2f)
```

typelbl	model									
	1	2	3	4	5	6	7	8	9	10
Impregum	31.29 3 0.01	31.33 3 0.01	31.19 3 0.02	31.18 3 0.06	31.23 3 0.02	31.21 3 0.01	31.19 3 0.02	31.23 3 0.01	31.21 3 0.03	31.23 3 0.01
Plaster	31.25 3 0.01	31.08 3 0.12	31.07 3 0.07	31.16 3 0.11	31.00 3 0.04	31.00 3 0.02	30.96 3 0.12	31.29 3 0.07	31.07 3 0.07	30.90 3 0.03
S-Steel	30.37 3 0.01	30.34 3 0.02	30.37 3 0.03	30.36 3 0.01	30.35 3 0.02	30.35 3 0.01	30.36 3 0.02	30.37 3 0.00	30.36 3 0.01	30.36 3 0.01

```
. anova distance type model type* model if group==43
```

```
Number of obs = 90      R-squared = 0.9851
Root MSE = .027246      Adj R-squared = 0.9779
```

Source	Partial SS	df	MS	F	Prob > F
Model	2.94475649	29	.101543327	136.79	0.0000
type	2.75075177	2	1.37537588	1852.74	0.0000
model	.061889896	9	.006876655	9.26	0.0000
type*model	.132114826	18	.007339713	9.89	0.0000
Residual	.044540725	60	.000742345		
Total	2.98929722	89	.033587609		

```
. table type model if group==43, c(mean distance n distance sd distance) format(%7.2f)
```

type	model									
type\bl	1	2	3	4	5	6	7	8	9	10
Impregum	40.66 3 0.01	40.72 3 0.00	40.65 3 0.01	40.64 3 0.03	40.64 3 0.01	40.65 3 0.01	40.61 3 0.01	40.66 3 0.00	40.65 3 0.01	40.65 3 0.01
Plaster	40.65 3 0.01	40.55 3 0.05	40.75 3 0.02	40.59 3 0.05	40.55 3 0.02	40.79 3 0.04	40.65 3 0.08	40.70 3 0.04	40.68 3 0.01	40.67 3 0.01
S-Steel	40.28 3 0.02	40.25 3 0.01	40.30 3 0.05	40.30 3 0.01	40.28 3 0.02	40.29 3 0.01	40.27 3 0.03	40.30 3 0.01	40.31 3 0.01	40.31 3 0.02

```
. anova distance type model type* model if group==44
```

```
Number of obs = 90      R-squared = 0.9548
Root MSE = .015648      Adj R-squared = 0.9330
```

Source	Partial SS	df	MS	F	Prob > F
Model	.310683858	29	.010713236	43.75	0.0000
type	.263743248	2	.131871624	538.57	0.0000
model	.010595793	9	.00117731	4.81	0.0001
type*model	.036344817	18	.002019156	8.25	0.0000
Residual	.014691357	60	.000244856		
Total	.325375215	89	.003655901		

```
. table type model if group==44, c(mean distance n distance sd distance) format(%7.2f)
```

type	model									
type\bl	1	2	3	4	5	6	7	8	9	10
Impregum	47.23 3 0.01	47.27 3 0.00	47.22 3 0.00	47.23 3 0.00	47.25 3 0.01	47.22 3 0.00	47.21 3 0.00	47.24 3 0.01	47.22 3 0.00	47.21 3 0.00
Plaster	47.14 3 0.02	47.09 3 0.01	47.10 3 0.01	47.10 3 0.01	47.08 3 0.01	47.15 3 0.01	47.08 3 0.00	47.14 3 0.01	47.05 3 0.01	47.06 3 0.00
S-Steel	47.13 3 0.02	47.12 3 0.01	47.16 3 0.05	47.17 3 0.01	47.15 3 0.04	47.16 3 0.01	47.17 3 0.05	47.16 3 0.00	47.17 3 0.00	47.16 3 0.00

```
. anova distance type model type* model if group==45
```

```
Number of obs = 90      R-squared = 0.9395
Root MSE = .020263     Adj R-squared = 0.9103
```

Source	Partial SS	df	MS	F	Prob > F
Model	.382535143	29	.013190867	32.13	0.0000
type	.16015753	2	.080078765	195.03	0.0000
model	.065652762	9	.007294751	17.77	0.0000
type*model	.156724851	18	.008706936	21.21	0.0000
Residual	.024635493	60	.000410592		
Total	.407170636	89	.004574951		

```
. table type model if group==45, c(mean distance n distance sd distance) format(%7.2f)
```

type	1	2	3	4	5	6	7	8	9	10
Impregum	17.21 3 0.00	17.21 3 0.01	17.20 3 0.01	17.22 3 0.01	17.21 3 0.01	17.20 3 0.00	17.21 3 0.01	17.18 3 0.01	17.19 3 0.01	17.22 3 0.01
Plaster	17.19 3 0.02	17.20 3 0.00	17.12 3 0.01	17.23 3 0.01	17.21 3 0.00	17.05 3 0.01	17.02 3 0.07	17.24 3 0.04	17.11 3 0.05	16.99 3 0.02
S-Steel	17.09 3 0.02	17.08 3 0.00	17.10 3 0.02	17.11 3 0.00	17.11 3 0.01	17.10 3 0.00	17.11 3 0.01	17.11 3 0.00	17.11 3 0.00	17.11 3 0.00

```
. anova distance type model type* model if group==46
```

```
Number of obs = 90      R-squared = 0.8669
Root MSE = .012059     Adj R-squared = 0.8025
```

Source	Partial SS	df	MS	F	Prob > F
Model	.056806257	29	.001958836	13.47	0.0000
type	.030587536	2	.015293768	105.18	0.0000
model	.008526503	9	.000947389	6.52	0.0000
type*model	.017692218	18	.000982901	6.76	0.0000
Residual	.008724747	60	.000145412		
Total	.065531004	89	.000736303		

```
. table type model if group==46, c(mean distance n distance sd distance) format(%7.2f)
```

type	1	2	3	4	5	6	7	8	9	10
Impregum	30.13 3 0.01	30.14 3 0.00	30.16 3 0.01	30.16 3 0.01	30.11 3 0.01	30.13 3 0.01	30.12 3 0.01	30.13 3 0.01	30.14 3 0.00	30.15 3 0.01
Plaster	30.17 3 0.02	30.18 3 0.00	30.15 3 0.01	30.20 3 0.01	30.20 3 0.01	30.22 3 0.01	30.16 3 0.01	30.20 3 0.01	30.18 3 0.02	30.16 3 0.00
S-Steel	30.14 3 0.01	30.12 3 0.00	30.16 3 0.04	30.15 3 0.00	30.15 3 0.01	30.15 3 0.01	30.14 3 0.02	30.16 3 0.00	30.17 3 0.01	30.17 3 0.00

```
. anova distance type model type* model if group==47
```

```

              Number of obs =      90      R-squared      = 0.9820
              Root MSE      = .026877      Adj R-squared = 0.9734

```

Source	Partial SS	df	MS	F	Prob > F
Model	2.36953211	29	.081708004	113.11	0.0000
type	2.09572743	2	1.04786371	1450.54	0.0000
model	.103635824	9	.011515092	15.94	0.0000
type*model	.170168861	18	.009453826	13.09	0.0000
Residual	.043343738	60	.000722396		
Total	2.41287585	89	.027110965		

```
. table type model if group==47, c(mean distance n distance sd distance) format(%7.2f)
```

typelbl	model									
	1	2	3	4	5	6	7	8	9	10
Impregum	40.42 3 0.01	40.41 3 0.01	40.30 3 0.00	40.32 3 0.03	40.33 3 0.01	40.33 3 0.03	40.32 3 0.00	40.31 3 0.04	40.31 3 0.01	40.32 3 0.03
Plaster	40.39 3 0.03	40.19 3 0.03	40.21 3 0.03	40.22 3 0.02	40.09 3 0.01	40.32 3 0.03	40.33 3 0.08	40.36 3 0.04	40.28 3 0.02	40.26 3 0.01
S-Steel	39.99 3 0.01	39.97 3 0.01	39.99 3 0.03	39.99 3 0.00	39.98 3 0.03	39.99 3 0.00	40.00 3 0.04	39.98 3 0.00	39.98 3 0.02	39.98 3 0.01

```
. anova distance type model type* model if group==48
```

```

              Number of obs =      90      R-squared      = 0.9809
              Root MSE      = .02456      Adj R-squared = 0.9717

```

Source	Partial SS	df	MS	F	Prob > F
Model	1.85772709	29	.064059555	106.20	0.0000
type	1.04091444	2	.520457222	862.86	0.0000
model	.272464132	9	.030273792	50.19	0.0000
type*model	.544348516	18	.030241584	50.14	0.0000
Residual	.03619075	60	.000603179		
Total	1.89391784	89	.021279976		

```
. table type model if group==48, c(mean distance n distance sd distance) format(%7.2f)
```

typelbl	model									
	1	2	3	4	5	6	7	8	9	10
Impregum	16.54 3 0.01	16.54 3 0.01	16.56 3 0.01	16.58 3 0.01	16.52 3 0.00	16.53 3 0.01	16.53 3 0.00	16.56 3 0.00	16.56 3 0.00	16.54 3 0.01
Plaster	16.63 3 0.04	16.60 3 0.01	16.25 3 0.04	16.57 3 0.01	16.61 3 0.01	16.23 3 0.04	16.29 3 0.04	16.58 3 0.01	16.34 3 0.09	16.26 3 0.03
S-Steel	16.71 3 0.00	16.70 3 0.01	16.71 3 0.02	16.69 3 0.00	16.69 3 0.01	16.70 3 0.01	16.68 3 0.02	16.69 3 0.01	16.71 3 0.01	16.69 3 0.01

```
. anova distance type model type* model if group==49
```

```
Number of obs = 90      R-squared = 0.9846
Root MSE = .04232      Adj R-squared = 0.9772
```

Source	Partial SS	df	MS	F	Prob > F
Model	6.8733753	29	.237012942	132.33	0.0000
type	5.5081407	2	2.75407035	1537.72	0.0000
model	.651615976	9	.072401775	40.43	0.0000
type*model	.713618633	18	.03964548	22.14	0.0000
Residual	.107460864	60	.001791014		
Total	6.98083617	89	.078436361		

```
. table type model if group==49, c(mean distance n distance sd distance) format(%7.2f)
```

typelbl	1	2	3	4	5	6	7	8	9	10
Impregum	30.27 3 0.01	30.25 3 0.01	30.03 3 0.02	30.10 3 0.06	30.09 3 0.02	30.11 3 0.06	30.07 3 0.02	30.09 3 0.08	30.08 3 0.01	30.08 3 0.04
Plaster	30.31 3 0.08	29.83 3 0.04	29.79 3 0.05	29.83 3 0.04	29.67 3 0.02	29.72 3 0.06	29.84 3 0.04	30.20 3 0.01	29.85 3 0.12	29.72 3 0.04
S-Steel	29.55 3 0.01	29.53 3 0.01	29.53 3 0.02	29.51 3 0.01	29.51 3 0.02	29.52 3 0.02	29.51 3 0.02	29.50 3 0.02	29.50 3 0.03	29.49 3 0.03

```
. anova distance type model type* model if group==50
```

```
Number of obs = 90      R-squared = 0.9961
Root MSE = .03498      Adj R-squared = 0.9942
```

Source	Partial SS	df	MS	F	Prob > F
Model	18.5597263	29	.639990561	523.04	0.0000
type	16.1627583	2	8.08137914	6604.55	0.0000
model	.717910126	9	.079767792	65.19	0.0000
type*model	1.67905788	18	.093280993	76.23	0.0000
Residual	.073416491	60	.001223608		
Total	18.6331428	89	.209361155		

```
. table type model if group==50, c(mean distance n distance sd distance) format(%7.2f)
```

typelbl	1	2	3	4	5	6	7	8	9	10
Impregum	14.59 3 0.01	14.58 3 0.01	14.28 3 0.02	14.33 3 0.07	14.39 3 0.03	14.42 3 0.08	14.36 3 0.03	14.35 3 0.09	14.34 3 0.01	14.36 3 0.05
Plaster	14.56 3 0.05	14.01 3 0.05	14.55 3 0.01	14.04 3 0.04	13.82 3 0.03	14.53 3 0.00	14.54 3 0.01	14.50 3 0.01	14.48 3 0.01	14.46 3 0.00
S-Steel	13.51 3 0.01	13.50 3 0.03	13.48 3 0.01	13.48 3 0.01	13.47 3 0.02	13.47 3 0.01	13.48 3 0.02	13.46 3 0.01	13.45 3 0.02	13.45 3 0.01

```
. log off
```

```
log: C:\Dudu\Von Berg\Data2m23.log
```

```
log type: text
```


Comparison of the means

log: C:\Dudu\Von Berg\Data2m23.log
log type: text
resumed on: 22 Mar 2006, 07:53:15

. oneway distance type if group==41, tabulate scheffe

typelbl	Summary of distance		
	Mean	Std. Dev.	Freq.
Impregum	15.04	0.06	30
Plaster	15.03	0.12	30
S-Steel	14.03	0.02	30
Total	14.70	0.48	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	20.104063	2	10.0520315	1517.52	0.0000
Within groups	.576285145	87	.006623967		
Total	20.6803482	89	.232363463		

Bartlett's test for equal variances: $\chi^2(2) = 81.8621$ Prob> $\chi^2 = 0.000$

Comparison of distance by typelbl (Scheffe)

Row Mean- Col Mean	Impregum	Plaster
Plaster	-0.01 0.782	
S-Steel	-1.01 0.000	-1.00 0.000

. oneway distance type if group==42, tabulate scheffe

typelbl	Summary of distance		
	Mean	Std. Dev.	Freq.
Impregum	31.23	0.05	30
Plaster	31.08	0.14	30
S-Steel	30.36	0.01	30
Total	30.89	0.39	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	12.9399282	2	6.46996408	927.06	0.0000
Within groups	.607173174	87	.006979002		
Total	13.5471013	89	.152214622		

Bartlett's test for equal variances: $\chi^2(2) = 101.1718$ Prob> $\chi^2 = 0.000$

Comparison of distance by typelbl (Scheffe)

Row Mean- Col Mean	Impregum	Plaster
Plaster	-0.15 0.000	
S-Steel	-0.87 0.000	-0.72 0.000

```
. oneway distance type if group==43, tabulate scheffe
```

typelbl	Summary of distance		
	Mean	Std. Dev.	Freq.
Impregum	40.66	0.03	30
Plaster	40.66	0.08	30
S-Steel	40.29	0.03	30
Total	40.53	0.18	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	2.75075177	2	1.37537588	501.61	0.0000
Within groups	.238545447	87	.002741902		
Total	2.98929722	89	.033587609		

Bartlett's test for equal variances: $\chi^2(2) = 49.1541$ Prob> $\chi^2 = 0.000$

Comparison of distance by typelbl
(Scheffe)

Row Mean- Col Mean	Impregum	Plaster
Plaster	0.00 0.972	
S-Steel	-0.37 0.000	-0.37 0.000

```
. oneway distance type if group==44, tabulate scheffe
```

typelbl	Summary of distance		
	Mean	Std. Dev.	Freq.
Impregum	47.23	0.02	30
Plaster	47.10	0.03	30
S-Steel	47.15	0.03	30
Total	47.16	0.06	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	.263743248	2	.131871624	186.15	0.0000
Within groups	.061631967	87	.000708413		
Total	.325375215	89	.003655901		

Bartlett's test for equal variances: $\chi^2(2) = 10.2315$ Prob> $\chi^2 = 0.006$

Comparison of distance by typelbl
(Scheffe)

Row Mean- Col Mean	Impregum	Plaster
Plaster	-0.13 0.000	
S-Steel	-0.08 0.000	0.05 0.000

```
. oneway distance type if group==45, tabulate scheffe
```

typelbl	Summary of distance		
	Mean	Std. Dev.	Freq.
Impregum	17.21	0.01	30
Plaster	17.14	0.09	30
S-Steel	17.10	0.01	30
Total	17.15	0.07	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	.16015753	2	.080078765	28.20	0.0000
Within groups	.247013106	87	.002839231		
Total	.407170636	89	.004574951		

Bartlett's test for equal variances: $\chi^2(2) = 136.3753$ Prob> $\chi^2 = 0.000$

Comparison of distance by typelbl
(Scheffe)

Row Mean-		
Col Mean	Impregum	Plaster
Plaster	-0.07 0.000	
S-Steel	-0.10 0.000	-0.03 0.068

```
. oneway distance type if group==46, tabulate scheffe
```

typelbl	Summary of distance		
	Mean	Std. Dev.	Freq.
Impregum	30.14	0.02	30
Plaster	30.18	0.02	30
S-Steel	30.15	0.02	30
Total	30.16	0.03	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	.030587536	2	.015293768	38.08	0.0000
Within groups	.034943468	87	.000401649		
Total	.065531004	89	.000736303		

Bartlett's test for equal variances: $\chi^2(2) = 5.6806$ Prob> $\chi^2 = 0.058$

Comparison of distance by typelbl
(Scheffe)

Row Mean-		
Col Mean	Impregum	Plaster
Plaster	0.04 0.000	
S-Steel	0.01 0.023	-0.03 0.000

```
. oneway distance type if group==47, tabulate scheffe
```

typelbl	Summary of distance		
	Mean	Std. Dev.	Freq.
Impregum	40.34	0.05	30
Plaster	40.26	0.09	30
S-Steel	39.98	0.02	30
Total	40.20	0.16	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	2.09572743	2	1.04786371	287.45	0.0000
Within groups	.317148423	87	.003645384		
Total	2.41287585	89	.027110965		

Bartlett's test for equal variances: $\chi^2(2) = 58.5537$ Prob> $\chi^2 = 0.000$

Comparison of distance by typelbl
(Scheffe)

Row Mean-		
Col Mean	Impregum	Plaster
Plaster	-0.07 0.000	
S-Steel	-0.35 0.000	-0.28 0.000

```
. oneway distance type if group==48, tabulate scheffe
```

typelbl	Summary of distance		
	Mean	Std. Dev.	Freq.
Impregum	16.55	0.02	30
Plaster	16.43	0.17	30
S-Steel	16.70	0.01	30
Total	16.56	0.15	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	1.04091444	2	.520457222	53.08	0.0000
Within groups	.853003399	87	.009804637		
Total	1.89391784	89	.021279976		

Bartlett's test for equal variances: $\chi^2(2) = 168.2924$ Prob> $\chi^2 = 0.000$

Comparison of distance by typelbl
(Scheffe)

Row Mean-		
Col Mean	Impregum	Plaster
Plaster	-0.11 0.000	
S-Steel	0.15 0.000	0.26 0.000

```
. oneway distance type if group==49, tabulate scheffe
```

typelbl	Summary of distance		
	Mean	Std. Dev.	Freq.
Impregum	30.12	0.08	30
Plaster	29.88	0.21	30
S-Steel	29.51	0.03	30
Total	29.84	0.28	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	5.5081407	2	2.75407035	162.70	0.0000
Within groups	1.47269547	87	.016927534		
Total	6.98083617	89	.078436361		

Bartlett's test for equal variances: $\chi^2(2) = 92.3283$ Prob> $\chi^2 = 0.000$

Comparison of distance by typelbl
(Scheffe)

Row Mean-		
Col Mean	Impregum	Plaster
Plaster	-0.24 0.000	
S-Steel	-0.60 0.000	-0.36 0.000

```
. oneway distance type if group==50, tabulate scheffe
```

typelbl	Summary of distance		
	Mean	Std. Dev.	Freq.
Impregum	14.40	0.11	30
Plaster	14.35	0.27	30
S-Steel	13.47	0.02	30
Total	14.07	0.46	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	16.1627583	2	8.08137914	284.60	0.0000
Within groups	2.4703845	87	.028395224		
Total	18.6331428	89	.209361155		

Bartlett's test for equal variances: $\chi^2(2) = 109.0900$ Prob> $\chi^2 = 0.000$

Comparison of distance by typelbl
(Scheffe)

Row Mean-		
Col Mean	Impregum	Plaster
Plaster	-0.05 0.492	
S-Steel	-0.92 0.000	-0.87 0.000

```
. log off
log: C:\Dudu\Von Berg\Data2m23.log
log type: text
paused on: 22 Mar 2006, 07:54:36
```

9. APPENDIX B

CAST DATA ANALYSIS OF VARIANCE AND TABLE OF MEANS

```
log: C:\Dudu\Von Berg\Casts output.log
log type: text
opened on: 28 Apr 2006, 09:18:37
```

```
. anova distance type model if group==41
```

```
Number of obs = 90      R-squared = 0.9170
Root MSE = .154756     Adj R-squared = 0.9053
```

Source	Partial SS	df	MS	F	Prob > F
Model	20.6326876	11	1.87569887	78.32	0.0000
type	20.0656184	2	10.0328092	418.92	0.0000
model	.567069167	9	.063007685	2.63	0.0103
Residual	1.86805093	78	.023949371		
Total	22.5007385	89	.252817287		

```
. table type model if group==41, c(mean distance sd distance n distance) col row f(%7.2f)
```

type	1	2	3	4	5	6	7	8	9	10	Total
Plaster	14.84 0.05 3	14.75 0.06 3	15.16 0.01 3	15.19 0.00 3	15.15 0.00 3	14.58 0.01 3	14.53 0.03 3	14.53 0.03 3	14.72 0.07 3	15.15 0.02 3	14.86 0.27 30
Impregum	15.19 0.01 3	15.20 0.01 3	15.18 0.00 3	15.17 0.01 3	15.16 0.00 3	15.20 0.00 3	15.19 0.00 3	15.19 0.00 3	15.17 0.00 3	14.84 0.00 3	15.15 0.11 30
S-Steel	14.07 0.01 3	14.04 0.02 3	14.05 0.01 3	14.03 0.01 3	14.02 0.01 3	14.03 0.00 3	14.03 0.01 3	14.03 0.00 3	14.03 0.01 3	14.03 0.01 3	14.03 0.02 30
Total	14.70 0.50 9	14.66 0.51 9	14.80 0.56 9	14.80 0.58 9	14.78 0.57 9	14.60 0.51 9	14.59 0.50 9	14.58 0.50 9	14.64 0.50 9	14.67 0.50 9	14.68 0.50 90

```
. anova distance type model if group==42
```

```
Number of obs = 90      R-squared = 0.9772
Root MSE = .065483     Adj R-squared = 0.9740
```

Source	Partial SS	df	MS	F	Prob > F
Model	14.3542234	11	1.3049294	304.32	0.0000
type	14.2066691	2	7.10333454	1656.53	0.0000
model	.147554322	9	.016394925	3.82	0.0005
Residual	.334470244	78	.00428808		
Total	14.6886937	89	.165041502		

```
. table type model if group==42, c(mean distance sd distance n distance) col row f(%7.2f)
```

	model
--	-------

type	1	2	3	4	5	6	7	8	9	10	Total
Plaster	30.99	30.93	30.98	30.97	30.86	30.82	30.78	30.79	30.94	31.21	30.93
	0.04	0.05	0.03	0.02	0.01	0.01	0.02	0.02	0.06	0.02	0.13
	3	3	3	3	3	3	3	3	3	3	30
Impregum	31.30	31.34	31.30	31.33	31.32	31.34	31.36	31.32	31.32	31.34	31.33
	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.02
	3	3	3	3	3	3	3	3	3	3	30
S-Steel	30.37	30.34	30.37	30.36	30.35	30.35	30.36	30.37	30.36	30.36	30.36
	0.01	0.02	0.03	0.01	0.02	0.01	0.02	0.00	0.01	0.01	0.01
	3	3	3	3	3	3	3	3	3	3	30
Total	30.89	30.87	30.89	30.89	30.84	30.84	30.83	30.83	30.87	30.97	30.87
	0.41	0.44	0.41	0.43	0.42	0.43	0.43	0.41	0.42	0.46	0.41
	9	9	9	9	9	9	9	9	9	9	90

```
. anova distance type model if group==43
```

```

              Number of obs =      90      R-squared      = 0.8701
              Root MSE      = .072848      Adj R-squared = 0.8518

```

Source	Partial SS	df	MS	F	Prob > F
Model	2.77257971	11	.252052701	47.50	0.0000
type	2.57531727	2	1.28765863	242.64	0.0000
model	.197262444	9	.021918049	4.13	0.0002
Residual	.413930289	78	.005306799		
Total	3.18651	89	.035803483		

```
. table type model if group==43, c(mean distance sd distance n distance) col row f(%7.2f)
```

type	model										Total
	1	2	3	4	5	6	7	8	9	10	
Plaster	40.51	40.52	40.80	40.77	40.73	40.47	40.38	40.46	40.51	40.62	40.58
	0.01	0.03	0.02	0.03	0.01	0.01	0.01	0.01	0.02	0.00	0.14
	3	3	3	3	3	3	3	3	3	3	30
Impregum	40.65	40.72	40.66	40.68	40.68	40.71	40.68	40.71	40.69	40.69	40.69
	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.02
	3	3	3	3	3	3	3	3	3	3	30
S-Steel	40.28	40.25	40.30	40.30	40.28	40.29	40.27	40.30	40.31	40.31	40.29
	0.02	0.01	0.05	0.01	0.02	0.01	0.03	0.01	0.01	0.02	0.03
	3	3	3	3	3	3	3	3	3	3	30
Total	40.48	40.50	40.59	40.58	40.57	40.49	40.44	40.49	40.50	40.54	40.52
	0.16	0.21	0.23	0.22	0.22	0.18	0.18	0.18	0.17	0.18	0.19
	9	9	9	9	9	9	9	9	9	9	90

```
. anova distance type model if group==44
```

```

              Number of obs =      90      R-squared      = 0.5611
              Root MSE      = .135611      Adj R-squared = 0.4992

```

Source	Partial SS	df	MS	F	Prob > F
Model	1.83406097	11	.166732815	9.07	0.0000
type	1.21725869	2	.608629344	33.10	0.0000
model	.616802278	9	.068533586	3.73	0.0006
Residual	1.43444042	78	.018390262		
Total	3.26850139	89	.036724735		

```
. table type model if group==44, c(mean distance sd distance n distance) col row f(%7.2f)
```

type	model										Total
	1	2	3	4	5	6	7	8	9	10	
Plaster	47.13	47.13	47.21	47.22	47.12	47.17	47.09	47.16	47.15	47.12	47.15
	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.04
	3	3	3	3	3	3	3	3	3	3	30
Impregum	47.24	47.99	47.25	47.27	47.29	47.29	47.28	47.29	47.83	47.28	47.40
	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.26
	3	3	3	3	3	3	3	3	3	3	30
S-Steel	47.13	47.12	47.16	47.17	47.15	47.16	47.17	47.16	47.17	47.16	47.15
	0.02	0.01	0.05	0.01	0.04	0.01	0.05	0.00	0.00	0.00	0.03
	3	3	3	3	3	3	3	3	3	3	30
Total	47.17	47.41	47.20	47.22	47.19	47.21	47.18	47.20	47.38	47.19	47.23
	0.06	0.43	0.04	0.04	0.08	0.06	0.08	0.06	0.33	0.07	0.19
	9	9	9	9	9	9	9	9	9	9	90

```
. anova distance type model if group==45
```

Number of obs = 90 R-squared = 0.4835
Root MSE = .098545 Adj R-squared = 0.4106

Source	Partial SS	df	MS	F	Prob > F
Model	.708999156	11	.064454469	6.64	0.0000
type	.267121422	2	.133560711	13.75	0.0000
model	.441877733	9	.049097526	5.06	0.0000
Residual	.757473467	78	.009711198		
Total	1.46647262	89	.01647722		

```
. table type model if group==45, c(mean distance sd distance n distance) col row f(%7.2f)
```

type	model										Total
	1	2	3	4	5	6	7	8	9	10	
Plaster	17.11	17.11	16.97	16.93	16.89	17.15	17.18	17.16	17.19	17.11	17.08
	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.11
	3	3	3	3	3	3	3	3	3	3	30
Impregum	17.11	17.13	17.13	17.17	17.16	17.16	17.18	17.14	17.16	17.71	17.21
	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.17
	3	3	3	3	3	3	3	3	3	3	30
S-Steel	17.09	17.08	17.10	17.11	17.11	17.10	17.11	17.11	17.11	17.11	17.10
	0.02	0.00	0.02	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01
	3	3	3	3	3	3	3	3	3	3	30
Total	17.11	17.11	17.07	17.07	17.06	17.14	17.16	17.14	17.15	17.31	17.13
	0.02	0.02	0.08	0.11	0.13	0.03	0.03	0.02	0.04	0.30	0.13
	9	9	9	9	9	9	9	9	9	9	90

```
. anova distance type model if group==46
```

Number of obs = 90 R-squared = 0.3329

Root MSE = .091087 Adj R-squared = 0.2389

Source	Partial SS	df	MS	F	Prob > F
Model	.323017089	11	.02936519	3.54	0.0005
type	.011156822	2	.005578411	0.67	0.5134
model	.311860267	9	.034651141	4.18	0.0002
Residual	.647156067	78	.008296873		
Total	.970173156	89	.010900822		

. table type model if group==46, c(mean distance sd distance n distance) col row f(%7.2f)

type	model										Total
	1	2	3	4	5	6	7	8	9	10	
Plaster	30.09	30.11	30.19	30.14	30.16	30.16	30.12	30.15	30.19	30.11	30.14
	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.03
	3	3	3	3	3	3	3	3	3	3	30
Impregum	30.02	30.05	30.05	30.09	30.08	30.07	30.06	30.08	30.08	30.65	30.12
	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.18
	3	3	3	3	3	3	3	3	3	3	30
S-Steel	30.14	30.12	30.16	30.15	30.15	30.15	30.14	30.16	30.17	30.17	30.15
	0.01	0.00	0.04	0.00	0.01	0.01	0.02	0.00	0.01	0.00	0.02
	3	3	3	3	3	3	3	3	3	3	30
Total	30.08	30.10	30.13	30.13	30.13	30.13	30.11	30.13	30.15	30.31	30.14
	0.05	0.03	0.06	0.03	0.04	0.04	0.04	0.04	0.05	0.25	0.10
	9	9	9	9	9	9	9	9	9	9	90

. anova distance type model if group==47

Number of obs = 90 R-squared = 0.7625
Root MSE = .148426 Adj R-squared = 0.7291

Source	Partial SS	df	MS	F	Prob > F
Model	5.51804239	11	.501640217	22.77	0.0000
type	4.67168096	2	2.33584048	106.03	0.0000
model	.846361433	9	.094040159	4.27	0.0002
Residual	1.71835193	78	.022030153		
Total	7.23639432	89	.081307801		

. table type model if group==47, c(mean distance sd distance n distance) col row f(%7.2f)

type	model										Total
	1	2	3	4	5	6	7	8	9	10	
Plaster	40.17	40.08	40.31	40.31	40.25	40.07	40.06	40.04	40.20	40.31	40.18
	0.03	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.04	0.01	0.11
	3	3	3	3	3	3	3	3	3	3	30
Impregum	40.33	41.03	40.34	40.37	40.38	40.35	40.36	40.37	40.92	40.88	40.53
	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.28
	3	3	3	3	3	3	3	3	3	3	30
S-Steel	39.99	39.97	39.99	39.99	39.98	39.99	40.00	39.98	39.98	39.98	39.98
	0.01	0.01	0.03	0.00	0.03	0.00	0.04	0.00	0.02	0.01	0.02
	3	3	3	3	3	3	3	3	3	3	30
Total	40.16	40.36	40.21	40.22	40.20	40.14	40.14	40.13	40.37	40.39	40.23
	0.15	0.51	0.17	0.18	0.18	0.17	0.17	0.18	0.42	0.40	0.29
	9	9	9	9	9	9	9	9	9	9	90

```
. anova distance type model if group==48
```

```
Number of obs =      90      R-squared      = 0.5501
Root MSE      = .081434      Adj R-squared = 0.4867
```

Source	Partial SS	df	MS	F	Prob > F
Model	.632477278	11	.057497934	8.67	0.0000
type	.390016289	2	.195008144	29.41	0.0000
model	.242460989	9	.02694011	4.06	0.0003
Residual	.517253711	78	.006631458		
Total	1.14973099	89	.012918326		

```
. table type model if group==48, c(mean distance sd distance n distance) col row f(%7.2f)
```

type	model										Total
	1	2	3	4	5	6	7	8	9	10	
Plaster	16.64	16.66	16.33	16.32	16.26	16.66	16.59	16.64	16.65	16.63	16.54
	0.00	0.00	0.02	0.05	0.01	0.00	0.00	0.00	0.01	0.01	0.16
	3	3	3	3	3	3	3	3	3	3	30
Impregum	16.60	16.60	16.60	16.61	16.59	16.58	16.57	16.61	16.60	16.55	16.59
	0.01	0.01	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.01	0.02
	3	3	3	3	3	3	3	3	3	3	30
S-Steel	16.71	16.70	16.71	16.69	16.69	16.70	16.68	16.69	16.71	16.69	16.70
	0.00	0.01	0.02	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.01
	3	3	3	3	3	3	3	3	3	3	30
Total	16.65	16.66	16.55	16.54	16.51	16.65	16.61	16.65	16.65	16.62	16.61
	0.04	0.04	0.17	0.17	0.20	0.05	0.05	0.03	0.05	0.06	0.11
	9	9	9	9	9	9	9	9	9	9	90

```
. anova distance type model if group==49
```

```
Number of obs =      90      R-squared      = 0.8850
Root MSE      = .148125      Adj R-squared = 0.8688
```

Source	Partial SS	df	MS	F	Prob > F
Model	13.167992	11	1.19709018	54.56	0.0000
type	12.285059	2	6.14252948	279.96	0.0000
model	.882933067	9	.098103674	4.47	0.0001
Residual	1.7113886	78	.021940879		
Total	14.8793806	89	.167184052		

```
. table type model if group==49, c(mean distance sd distance n distance) col row f(%7.2f)
```

type	model										Total
	1	2	3	4	5	6	7	8	9	10	
Plaster	29.96	29.80	29.81	29.81	29.65	29.64	29.61	29.58	29.83	30.21	29.79
	0.07	0.02	0.03	0.07	0.03	0.02	0.02	0.02	0.09	0.01	0.19
	3	3	3	3	3	3	3	3	3	3	30
Impregum	30.31	30.92	30.29	30.30	30.30	30.27	30.27	30.31	30.77	30.24	30.40
	0.01	0.01	0.00	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.23
	3	3	3	3	3	3	3	3	3	3	30
S-Steel	29.55	29.53	29.53	29.51	29.51	29.52	29.51	29.50	29.50	29.49	29.51
	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03
	3	3	3	3	3	3	3	3	3	3	30
Total	29.94	30.09	29.88	29.88	29.82	29.81	29.80	29.79	30.03	29.98	29.90
	0.33	0.64	0.33	0.35	0.37	0.35	0.36	0.39	0.57	0.37	0.41
	9	9	9	9	9	9	9	9	9	9	90

```
. anova distance type model if group==50
```

```

              Number of obs =      90      R-squared      = 0.8607
              Root MSE      = .208728    Adj R-squared = 0.8410

```

Source	Partial SS	df	MS	F	Prob > F
Model	20.9891267	11	1.90810242	43.80	0.0000
type	19.7671652	2	9.88358258	226.86	0.0000
model	1.22196151	9	.135773501	3.12	0.0030
Residual	3.39825596	78	.043567384		
Total	24.3873826	89	.274015535		

```
. table type model if group==50, c(mean distance sd distance n distance) col row f(%7.2f)
```

type	1	2	3	4	5	model 6	7	8	9	10	Total
Plaster	14.07 0.09 3	13.88 0.02 3	14.48 0.00 3	14.48 0.01 3	14.42 0.01 3	13.66 0.03 3	13.71 0.02 3	13.63 0.02 3	13.92 0.13 3	14.43 0.01 3	14.07 0.35 30
Impregum	14.53 0.01 3	15.08 0.01 3	14.52 0.00 3	14.52 0.00 3	14.54 0.01 3	14.52 0.00 3	14.52 0.01 3	14.53 0.00 3	14.94 0.00 3	14.52 0.00 3	14.62 0.20 30
S-Steel	13.51 0.01 3	13.50 0.03 3	13.48 0.01 3	13.48 0.01 3	13.47 0.02 3	13.47 0.01 3	13.48 0.02 3	13.46 0.01 3	13.45 0.02 3	13.45 0.01 3	13.47 0.02 30
Total	14.04 0.45 9	14.15 0.71 9	14.16 0.51 9	14.16 0.51 9	14.15 0.51 9	13.88 0.48 9	13.90 0.47 9	13.87 0.50 9	14.10 0.66 9	14.13 0.51 9	14.06 0.52 90

COMPARISON OF THE TYPES

. oneway distance type if group==41, tabulate scheffe

type	Summary of distance		
	Mean	Std. Dev.	Freq.
Plaster	14.860633	.26884177	30
Impregum	15.149033	.10691004	30
S-Steel	14.034833	.01624825	30
Total	14.6815	.50280939	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	20.0656184	2	10.0328092	358.44	0.0000
Within groups	2.4351201	87	.027989886		
Total	22.5007385	89	.252817287		

Bartlett's test for equal variances: $\chi^2(2) = 131.6893$ Prob> $\chi^2 = 0.000$

Comparison of distance by type (Scheffe)

Row Mean-		
Col Mean	Plaster	Impregum
Impregum	.2884 0.000	
S-Steel	-.8258 0.000	-1.1142 0.000

. oneway distance type if group==42, tabulate scheffe

type	Summary of distance		
	Mean	Std. Dev.	Freq.
Plaster	30.9274	.12665827	30
Impregum	31.328333	.01891238	30
S-Steel	30.3599	.01488427	30
Total	30.871878	.406253	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	14.2066691	2	7.10333454	1282.07	0.0000
Within groups	.482024567	87	.005540512		
Total	14.6886937	89	.165041502		

Bartlett's test for equal variances: $\chi^2(2) = 139.8494$ Prob> $\chi^2 = 0.000$

Comparison of distance by type (Scheffe)

Row Mean-		
Col Mean	Plaster	Impregum
Impregum	.400933 0.000	
S-Steel	-.5675 0.000	-.968433 0.000

```
. oneway distance type if group==43, tabulate scheffe
```

type	Summary of distance		
	Mean	Std. Dev.	Freq.
Plaster	40.5775	.14124148	30
Impregum	40.687767	.02217436	30
S-Steel	40.286733	.02519433	30
Total	40.517333	.18921808	90

Source	Analysis of Variance				
	SS	df	MS	F	Prob > F
Between groups	2.57531727	2	1.28765863	183.29	0.0000
Within groups	.611192733	87	.007025204		
Total	3.18651	89	.035803483		

Bartlett's test for equal variances: $\chi^2(2) = 114.8125$ Prob> $\chi^2 = 0.000$

Comparison of distance by type
(Scheffe)

Row Mean- Col Mean	Plaster	Impregum
Impregum	.110267 0.000	
S-Steel	-.290767 0.000	-.401033 0.000

```
. oneway distance type if group==44, tabulate scheffe
```

type	Summary of distance		
	Mean	Std. Dev.	Freq.
Plaster	47.150533	.03985468	30
Impregum	47.399067	.26154395	30
S-Steel	47.154233	.02718225	30
Total	47.234611	.19163699	90

Source	Analysis of Variance				
	SS	df	MS	F	Prob > F
Between groups	1.21725869	2	.608629344	25.81	0.0000
Within groups	2.0512427	87	.023577502		
Total	3.26850139	89	.036724735		

Bartlett's test for equal variances: $\chi^2(2) = 145.5342$ Prob> $\chi^2 = 0.000$

Comparison of distance by type
(Scheffe)

Row Mean- Col Mean	Plaster	Impregum
Impregum	.248533 0.000	
S-Steel	.0037 0.996	-.244833 0.000

```
. oneway distance type if group==45, tabulate scheffe
```

type	Summary of distance		
	Mean	Std. Dev.	Freq.
Plaster	17.079933	.10544289	30
Impregum	17.205933	.17346925	30
S-Steel	17.104867	.01213071	30
Total	17.130244	.12836363	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	.267121422	2	.133560711	9.69	0.0002
Within groups	1.1993512	87	.013785646		
Total	1.46647262	89	.01647722		

Bartlett's test for equal variances: $\chi^2(2) = 113.5159$ Prob> $\chi^2 = 0.000$

Comparison of distance by type
(Scheffe)

Row Mean- Col Mean	Plaster	Impregum
Impregum	.126 0.000	
S-Steel	.024933 0.714	-.101067 0.005

```
. oneway distance type if group==46, tabulate scheffe
```

type	Summary of distance		
	Mean	Std. Dev.	Freq.
Plaster	30.142767	.03245122	30
Impregum	30.124367	.17803728	30
S-Steel	30.151	.0178654	30
Total	30.139378	.104407	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	.011156822	2	.005578411	0.51	0.6046
Within groups	.959016333	87	.011023176		
Total	.970173156	89	.010900822		

Bartlett's test for equal variances: $\chi^2(2) = 138.0721$ Prob> $\chi^2 = 0.000$

Comparison of distance by type
(Scheffe)

Row Mean- Col Mean	Plaster	Impregum
Impregum	-.0184 0.795	
S-Steel	.008233 0.955	.026633 0.619

```
. oneway distance type if group==47, tabulate scheffe
```

type	Summary of distance		
	Mean	Std. Dev.	Freq.
Plaster	40.178867	.10848637	30
Impregum	40.5344	.27624459	30
S-Steel	39.9841	.01892153	30
Total	40.232456	.28514523	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	4.67168096	2	2.33584048	79.24	0.0000
Within groups	2.56471337	87	.029479464		
Total	7.23639432	89	.081307801		

Bartlett's test for equal variances: $\chi^2(2) = 125.0434$ Prob> $\chi^2 = 0.000$

Comparison of distance by type
(Scheffe)

Row Mean-		
Col Mean	Plaster	Impregum
Impregum	.355533 0.000	
S-Steel	-.194767 0.000	-.5503 0.000

```
. oneway distance type if group==48, tabulate scheffe
```

type	Summary of distance		
	Mean	Std. Dev.	Freq.
Plaster	16.538567	.15983713	30
Impregum	16.591467	.02066437	30
S-Steel	16.696933	.01490414	30
Total	16.608989	.11365881	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	.390016289	2	.195008144	22.33	0.0000
Within groups	.7597147	87	.008732353		
Total	1.14973099	89	.012918326		

Bartlett's test for equal variances: $\chi^2(2) = 160.4045$ Prob> $\chi^2 = 0.000$

Comparison of distance by type
(Scheffe)

Row Mean-		
Col Mean	Plaster	Impregum
Impregum	.0529 0.096	
S-Steel	.158367 0.000	.105467 0.000

```
. oneway distance type if group==49, tabulate scheffe
```

type	Summary of distance		Freq.
	Mean	Std. Dev.	
Plaster	29.789033	.18768471	30
Impregum	30.3985	.23151491	30
S-Steel	29.5144	.0251925	30
Total	29.900644	.40888146	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	12.285059	2	6.14252948	205.99	0.0000
Within groups	2.59432167	87	.029819789		
Total	14.8793806	89	.167184052		

Bartlett's test for equal variances: $\chi^2(2) = 88.4537$ Prob> $\chi^2 = 0.000$

Comparison of distance by type
(Scheffe)

Row Mean-		
Col Mean	Plaster	Impregum
Impregum	.609467 0.000	
S-Steel	-.274633 0.000	-.8841 0.000

```
. oneway distance type if group==50, tabulate scheffe
```

type	Summary of distance		Freq.
	Mean	Std. Dev.	
Plaster	14.0684	.34530552	30
Impregum	14.622533	.19874429	30
S-Steel	13.4748	.02413811	30
Total	14.055244	.52346493	90

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	19.7671652	2	9.88358258	186.11	0.0000
Within groups	4.62021747	87	.053105948		
Total	24.3873826	89	.274015535		

Bartlett's test for equal variances: $\chi^2(2) = 114.2391$ Prob> $\chi^2 = 0.000$

Comparison of distance by type
(Scheffe)

Row Mean-		
Col Mean	Plaster	Impregum
Impregum	.554133 0.000	
S-Steel	-.5936 0.000	-1.14773 0.000

```
. log close
log: C:\Dudu\Von Berg\Casts output.log
log type: text
closed on: 28 Apr 2006, 09:33:43
```


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